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Entered at the Post Office at Lancaster, Pa., March 14, 1928, as second-class matter under act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on July 3, 1919.

Published by

THE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA

Prince and Lemon Streets, Lancaster, Penna., and
Benjamin Franklin Parkway at Twentieth St., Philadelphia, Penna.

SIX DOLLARS PER YEAR (Foreign Postage Additional) SINGLE NUMBERS, SIXTY CENTS

Indexes to the semi-annual volumes of the JOURNAL are published with the June and December numbers. The contents are also indexed in *The Industrial Arts Index.*

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Journal
of
The Franklin Institute

Devoted to Science and the Mechanic Arts

Vol. 226 OCTOBER, 1938 No. 4

REPORT ON THE WORK OF THE BARTOL RESEARCH FOUNDATION, 1937–38.*

MADE TO THE MEMBERSHIP OF THE FRANKLIN INSTITUTE

BY

W. F. G. SWANN, D.Sc., Director.

INTRODUCTION.

During the last ten years or so the Reports of the Director of the Bartol Research Foundation have echoed prominently, among the stories of many things in the field of its interests, the trials and tribulations of the growth of our knowledge of cosmic-rays.

At the beginning of this period our knowledge of the phenomenon was so meagre that there was considerable doubt in the minds of men of science as to whether the designation "ray" was really appropriate at all. As late as 1928,[1] I wrote in the JOURNAL of the Institute a paper which discussed the possibility of detecting individual cosmic-rays, if there were such things; and the feeling of most physicists at that time was doubtless one which would have regarded the hope of such detection as unduly optimistic. Today, largely through the development of the Geiger-Mueller counter, the detection of individual cosmic-rays and the measurement of the number of such rays passing through our apparatus in any given time is a matter of regular routine.

* Presented at the Stated Meeting held on April 20, 1938.

[1] W. F. G. Swann, JOUR. FRANK. INST., **206**, 771 (1928).

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

While we do not yet know the complete story of all that is concerned in the origin and nature of those rays which enter our atmosphere and which we call the primary cosmic-rays, we have learned a great deal. From the way in which cosmic-ray phenomena vary over the surface of the earth, we have come to believe that a portion, if not all, of the incoming rays are charged particles, some of them possessing energies comparable with 10,000 million electron volts, or more. Very important advances in our knowledge of these matters, particularly with regard to the effect of the earth's magnetism upon the rays and with the conclusions to be drawn from these effects as regards energy and sign of charge carried by the rays, have been made by Dr. T. H. Johnson of our laboratory and have been recorded in my former reports.

Relevant Introductory Material in Relation to Cosmic-Ray Showers.—One of the most remarkable phenomena produced by cosmic-rays is that of giving rise to what are called showers of charged particles on impact of the rays with matter. The first observation of a phenomenon of the type which we now attribute to these showers was made by G. Hoffmann in Germany;[2] and what was perhaps the first demonstration in unmistakable form of the existence of such a shower of *large size* was made by Dr. J. C. Street and myself in our laboratory. A picture representing three such showers, which was obtained in 1932, is shown in Fig. 1, in which it will suffice to say that the hill-like structures in the curves are representative of the phenomenon in question. The three curves correspond to three different pressures in the ionization chamber. Since that time, the study of these cosmic-ray showers has advanced by leaps and bounds; and the investigations at the Bartol Foundation have contributed materially to the advance of our knowledge.

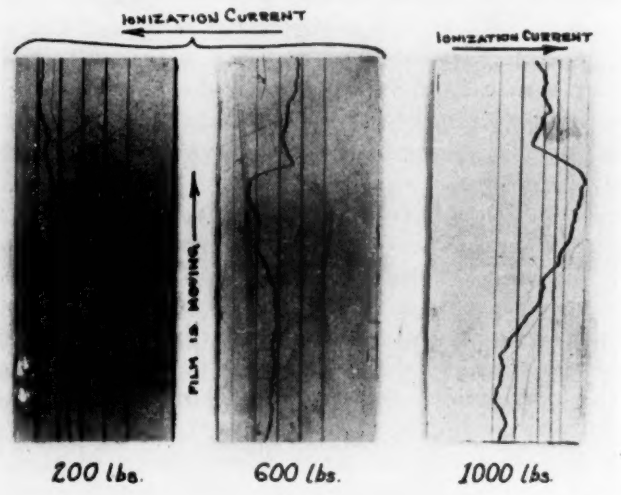
In the light of these considerations, I was led in 1933[3] to conclude that a large portion of that which was actually measured as cosmic radiation in the atmosphere was probably representative of these showers.

[2] G. Hoffmann and F. Lindholm, *Gerl. Beitr.*, **20**, 12 (1928); G. Hoffmann and W. S. Pforte, *Phys. Zeit.*, **31**, 347 (1930).

[3] W. F. G. Swann, *Phys. Rev.*, **44**, 1025 (1933).

Experiments by Dr. and Mrs. C. G. Montgomery,[4] by Dr. T. H. Johnson,[5] and by others have shown [6] that the production of these showers increases with altitude more rapidly than does the cosmic radiation itself. The considerations to be drawn from such experiments resulted in an extension of the ideas above cited as to the importance of shower phenomena in cosmic-ray theories; and the ideas concerned have

FIG. 1.



Hoffmann Stösse.

been developed in several papers which I have written on the matter over the period of the last four years [7] and which are designed to show that the so-called soft component of the cosmic radiation has its origin entirely in this form.

Experiments by Dr. and Mrs. Montgomery and myself in

[4] C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, **47**, 429 (1935).

[5] T. H. Johnson, *Phys. Rev.*, **45**, 569 (1934).

[6] R. D. Bennett, G. S. Brown, and H. A. Rahmel, *Phys. Rev.*, **47**, 339 (1935); B. Rossi and S. de Benedetti, *Ricerca Scient.*, **5**, 1 (1934).

[7] W. F. G. Swann, *Phys. Rev.*, **46**, 828 (1934); *Phys. Rev.*, **47**, 250 (1935); *Ohio Jour. Science*, **35**, 311 (1935); *Phys. Rev.*, **48**, 641 (1935); *Phys. Rev.*, **50**, 1103 (1936).

1935 [8] showed that the cosmic-ray shower particles from one piece of matter were themselves capable of giving rise to other particles in another piece, and indeed, evidence suggesting the likelihood of such a phenomenon had already been obtained in the cloud chamber experiments of Dr. G. L. Locher performed in our laboratory.[9]

In making this survey of shower phenomena, it is not my intention to imply an undue share in discovery to the Bartol Foundation. Many observers working in all parts of the world have contributed to the advances which have been made. However, as this presentation is in the nature of a report, it is perhaps not out of place to make reference to those of our own contributions in this field in the past which have specific reference to the present state of the subject and to those investigations of which I have more specifically to speak this evening.

Further Relevant Introductory Material in Relation to Cosmic-Ray Theories.—The development of the quantum theory of atomic structure is another field of physics which has progressed with leaps and bounds within the last decade, so that it has caught up to some extent with the experimental facts in the cosmic-ray field and has been a useful guide in providing correlations and interpretations of the phenomena.

A theory originally devised by H. A. Bethe and W. Heitler provided the quantum theory story of the loss of energy of a charged particle in passing through matter, and the consequences of this theory have been recently applied by several investigators to cosmic-rays [10] to the end of providing a story in which a portion of that which is observed is really the progeny, in the form of positive and negative electrons, removed through many generations from a primary which presumably entered the atmosphere with high energy, producing shower particles, which themselves produced shower particles, and so on. The net result of this is to provide for a situation which is ultimately very similar to that envisaged in the theory which I gave in 1934 and which was founded upon

[8] C. G. Montgomery, D. D. Montgomery, and W. F. G. Swann, *Phys. Rev.*, **47**, 512 (1935).

[9] G. L. Locher, *Phys. Rev.*, **44**, 779 (1933).

[10] H. J. Bhabha and W. Heitler, *Proc. Roy. Soc.*, **A159**, 432 (1937); J. F. Carlson and J. H. Oppenheimer, *Phys. Rev.*, **51**, 220 (1937).

the hypothesis that the particles of the primary radiation produce secondaries along their paths to a degree proportional to their energy. The quantum theory to which I have referred is also capable of extension to such phenomena as were revealed in the experiments of Dr. and Mrs. Montgomery and myself already referred to, and in which the shower particles produced in one body were able themselves to produce other shower particles in something else.

With the foregoing preliminary survey, it will be well, therefore, to state the conventional view which prevails at the present time in relation to the cosmic-ray phenomena of which we are speaking, bearing in mind that the ideas involved are to some extent in a state of flux.

We then vision the rays entering the atmosphere as of two kinds: Electrons, and charged particles heavier than electrons and concerning whose nature there is, at the present time, some doubt. Each of these groups of particles is possessed of a wide range of energy. The former group is the origin, through its progeny, of what has formerly been observed in the atmosphere as the soft component of the cosmic radiation. Its individual particles may be called the soft component primaries. The others constitute or are the origin of what has been measured as the hard component primaries.

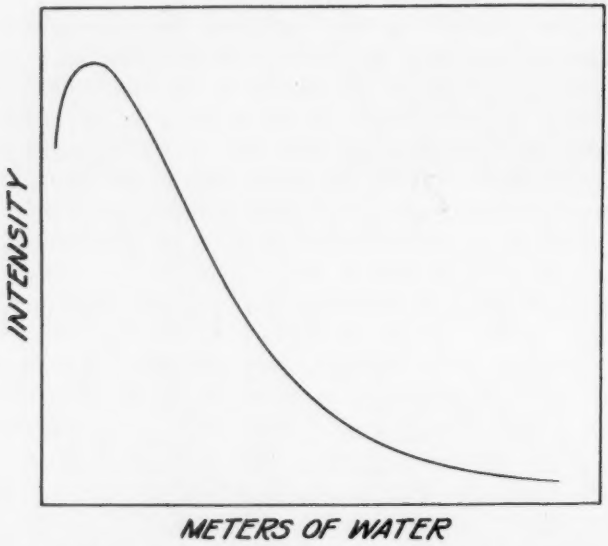
In contrast to the older views, according to which soft component primaries pass right through the atmosphere in numbers which diminish with the depth of penetration, the conventional picture today is to the effect that these primary electrons penetrate but a relatively small distance into the atmosphere. They disappear by the production of photons. These photons on striking other atoms produce positive and negative electrons which carry the penetration still further but themselves disappear by the production of other photons which continue the story.

When the whole matter is worked out, it turns out that, on entry into the atmosphere, we have only the primaries. As we descend further, the total number of rays is increased by the creation of the offspring, but with further descent a maximum, and then a decrease, result. The fact is that the more numerous members of the progeny, which are of smaller

energy than the others, lose so much more of their energy in ionization than in propagation that the death rate of the assembly becomes greater than the birth rate, and the number of rays continues to decrease with increase of depth. Superposed upon this phenomenon, we have the story of the hard component, and our measurements represent a combination of the two.

As far as the soft component alone is concerned, we should expect upon this theory, or indeed also on the closely related theory which I gave in 1934, a curve of intensity versus depth of the type shown in Fig. 2; and unless the hard com-

FIG. 2.



ponent should iron out the hump at P, we should expect this hump to be found in our measurements of cosmic-ray intensity at different altitudes. As stated in my former reports, this hump was discovered by E. Regener in Europe and by ourselves in the Bartol Foundation almost simultaneously, our own observations being obtained on the stratosphere flight of Explorer II.[11] Since that time, the hump has also been ob-

[11] W. F. G. Swann, G. L. Locher, W. E. Danforth, C. G. Montgomery and D. D. Montgomery, National Geographic Society, Contributed Technical Papers, Stratosphere Series, No. 2 (1936).

served by the unmanned balloon flights made by Dr. Johnson and others, and to these I shall presently refer.

COSMIC-RAY SHOWERS.

I have already referred to the production of cosmic-ray showers in substances like lead. Occasionally it is found that when a cosmic-ray particle enters a slab of lead, two or more particles emerge. Sometimes thousands of particles emerge. The large showers are enormously less frequent than the small ones, and the whole phenomenon associated with them is so drastically impressive as to have rendered quite common the belief that the large showers have an origin different from that of the small showers. While it was natural to think of the latter as originating by the creation of progeny of the original ray in the lead according to the principles I have sketched, there was a vague feeling that the large showers required something more drastic, the complete explosion of an atom, or the immediate collapse or transformation of some high energy cosmic-ray particle into a large number of low energy particles as the result of some peculiar kind of impact with an atom.

Stimulated by such experiments as those performed at the Bartol Foundation, to which I have already referred and in which shower particles themselves produce shower particles, there was an alternative view to the effect that a large shower could originate by the creation of various generations of progeny; but it seemed that a large piece of lead would be necessary to account for the progeny, and then there was the difficulty as to how the progeny could emerge from the lead at any great distances from the surface. The difficulties in these connections were such as to have caused certain physicists to invent entirely new and special theories to account for large showers.

A Theory of the Creation of Large Showers.—One of the first suspicions that the phenomena concerned with the relationship between large and small showers might be simpler in principle came when Dr. and Mrs. Montgomery showed that there was continuity between the large and small showers as regards the frequency of production. In fact, as cited in my former reports, the Montgomerys showed [12]

[12] C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, **48**, 786 (1935).

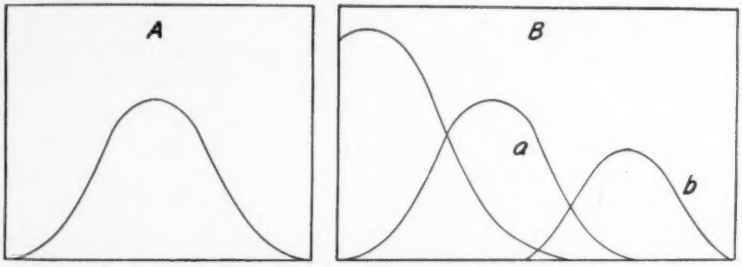
that if $f(N)dN$ is the average number of showers emerging from a piece of lead with numbers of the rays lying between N and $N + dN$, per unit of time, and for a given intensity of cosmic-rays falling upon the lead, then $f(N)$ is of the form A/N^3, giving thus much greater prominence to small than to large showers. However, the important thing is that this law fitted the whole range from the smallest showers which Dr. and Mrs. Montgomery measured up to the largest showers to which I have referred, giving, therefore, strong evidence in favor of a close connection between the origins of the different types of showers. Moreover, for a given intensity of cosmic radiation emerging from the lead, this law was, to a large extent, independent of the thickness of the lead used, so long as the thickness exceeded a certain minimum.

Now Dr. and Mrs. Montgomery have recently carried out a theoretical investigation in which they have shown that the ordinary theory of shower production through the creation of successive generations of progeny is capable of accounting for these large showers from a thin piece of lead as well as for the small showers. One's intuition might lead one to suppose that if, on the average, the creation of progeny by an incident cosmic-ray was to result in showers of an average size of 20 rays emerging, the chance of progeny being created at such a rapid rate in that piece of lead as to result in a 1000 ray shower emerging would be extremely small, just as, if the average deaths in a year were two million, the chance that in some particular year it was a hundred million would be very small. It is true that the statistical theory does give a small chance for the creation of these large showers, but it turns out that the degree of smallness of this chance is exactly that corresponding to experiment and is in harmony with the inverse N^3 law.

You will not thank me if I turn this report into a discourse on the intricacies of statistics. I would run the danger of your placing it in one of the categories of classification cited by one who said that there are three kinds of lies: lies, damned lies, and statistics. However, I do feel that there is real beauty in the idea which is fundamental to the success of the theory of Dr. and Mrs. Montgomery; and I should like to give a brief picture of the element involved.

Suppose that we imagine a piece of lead 1 cm. thick. While it is very solid to the eye of our vision, it is to some extent porous for the passage of small entities like cosmic-rays. I have before used the illustration that this hall, packed to the ceiling with chairs, would be very full of things when the phenomenon of an elephant walking through it was under discussion. Nevertheless, I have no doubt that a fly could occasionally find a path by which he could go right through the room in a straight line. Our piece of lead is, therefore, like the room packed with chairs, and the cosmic-rays are like the flies. If a group of cosmic-rays descend upon the lead, a certain number of them will get right through without encountering an obstacle. If we try the experiment a number of times, the numbers of rays which get through will be

FIG. 3.



different in the different trials, but they will be distributed about an average; and the number of occasions in which a number of rays, appreciably different from this average, will succeed in passing through will be very few. Suppose that we repeated the experiment with a thinner piece of lead. Again there would be an average, and a distribution of possibilities about that average. This average would be different from the former one. Suppose we take a large number of different thicknesses of lead, we shall get a large number of different averages, each with its own little distribution about that average. In Fig. 3*A*, we have plotted vertically the fraction of the number of trials in which the number of rays given by the abscissæ would emerge, without impact, from the lead. In Fig. 3*B*, we have represented similar curves for different thicknesses of lead, the graphs

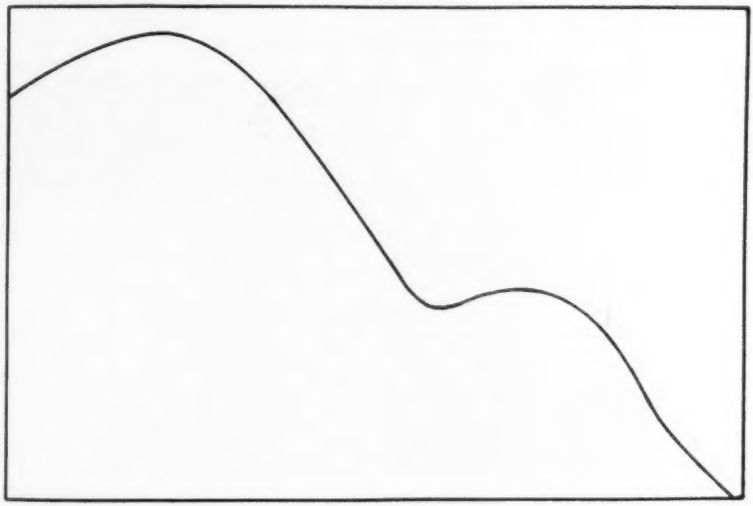
being in all cases purely qualitative and intended only for illustration. Now, in actuality, the growth of the shower results in a situation which involves a combination of an infinite number of such curves as Fig. 3*B*, each one being separated from the next by an infinitesimal amount. For, every time one of the entering rays performs the act concerned with the creation of progeny, it disappears from the class of rays which went through undisturbed and which might be representative, for example, of the curve (*a*) in Fig. 3*B*, and the progeny of the first generation now start to pass through a thinner piece of lead and are in line to be the originators of some other curve such as (*b*) in Fig. 3*B*. These in turn repeat the story, always with a little more complexity than is here described, but without departure from the general fundamental ideas. The net result is that if, for different trials, we should plot against the size of the emerging shower the fraction of the cases in which we obtained that size, there would result a curve which had characteristics similar to that obtained by adding together the infinite number of curves of which the few drawn in Fig. 3*B* are supposed to be the representatives. The important feature is that, as will be obvious, this resultant curve would have a much wider spread than any of the individual curves from which it was obtained. Indeed, calculation shows that the resulting curve does not even have a maximum in the vicinity of its average value, but falls off continually with increase of the number of emerging rays. As a matter of illustration we have drawn the curves in Fig. 3*B* in such a way as to add up to a result of this type, which result is represented in Fig. 4. Had we employed an infinite number of infinitely close curves in Fig. 3*B*, the wavy nature of Fig. 4 would have been absent.

The net result, therefore, of the theory of Dr. and Mrs. Montgomery is to show that a much wider range of shower sizes from a relatively thin piece of lead is to be expected than might be anticipated from the most naive, but intuitive, view as to what is to be expected from the statistics of the problem.

Further elements of interest which result from the investigation are the following: Assuming the law of distribution of showers to be that of the inverse N^3, as above cited, Dr. and Mrs. Montgomery have determined the distribution of

energies in the shower producing rays necessary to lead, through their theory, to that law. The results are in conformity with the energy distribution determined by C. Anderson, P. M. S. Blackett, and others from cloud chamber data. Moreover, this energy distribution at sea-level is in harmony with the energy distribution necessary for the primary rays entering the atmosphere in order that, through the formation of progeny in the atmosphere, they should give rise to the variation of measured cosmic-ray intensity with altitude which is consistent with the facts.

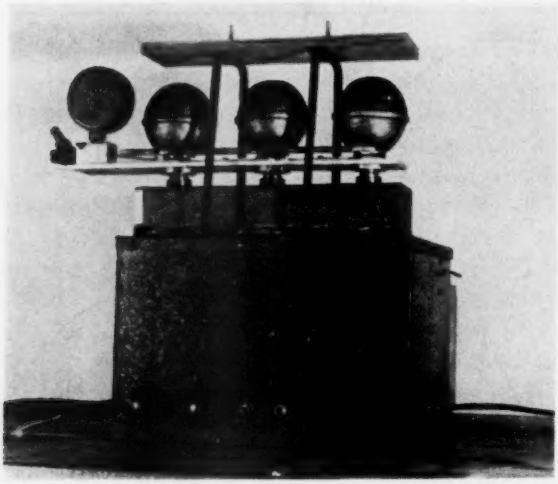
FIG. 4.



Variation of Shower Production with Depth.—I have already referred to the variation of shower production with altitude above the earth's surface and there is naturally considerable interest in investigating the variation of this phenomenon below the surface of the earth. Indeed, experiments on this matter have been performed, and so far with the results indicating that while the shower production decreases more rapidly than the cosmic radiation as we descend through the atmosphere, the law gradually changes as we extend the observations to regions below the earth's surface, the extension being in the direction of the shower production

becoming more nearly proportional at the various depths to the cosmic-ray intensity. In order to sift this matter further, Dr. and Mrs. Montgomery performed some experiments last summer in a gypsum mine down to a depth of about 100 feet below the surface of the ground.[13] They confined their attention to showers in which the number of rays recorded by their apparatus in any one shower was greater than 20. That apparatus is shown in Fig. 5, and its general features are described in the caption.

FIG. 5.



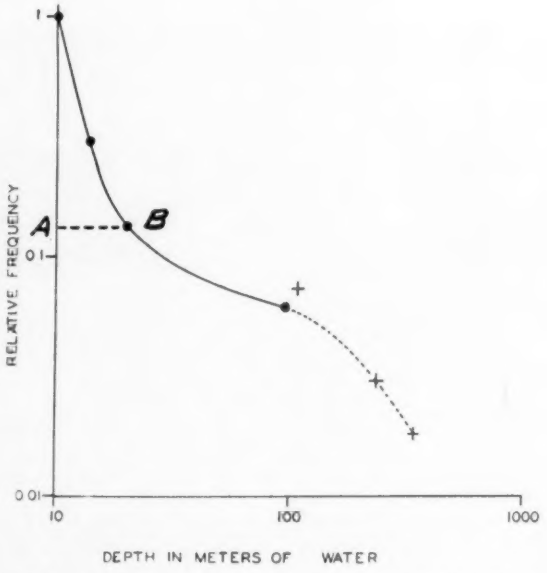
The three spheres are the ionization chambers in which the rays from the bursts are observed. They are filled with gas under pressure. The box contains the necessary amplifying equipment connected, through one of the leads shown, to the recorder.

Figure 6, which should be interpreted in the sense of its caption, shows the results of this experiment which, however, can only be considered as preliminary. The ordinates represent the relative frequencies of the bursts, and the abscissæ the distance below the top of the homogeneous water equivalent atmosphere. It is to be noticed that initially the decrease in the number of large showers with increase of

[13] The Bartol Foundation is indebted to the Victor Plaster Company for the courtesies afforded in the opportunity to use the mine.

depth is very rapid. In other words, the rapid decrease of shower phenomena characteristic of the atmosphere becomes perpetuated as regards these large showers below the surface of the earth for at least the distance represented by AB in Fig. 6. At greater depths, however, the decrease with increase of depth is more gradual. The explanation of this phenomenon is not at present obvious; but one is tempted to

FIG. 6.



In order to coördinate this curve with the text, it should be observed that the relative frequency and depth are not plotted on a linear scale.

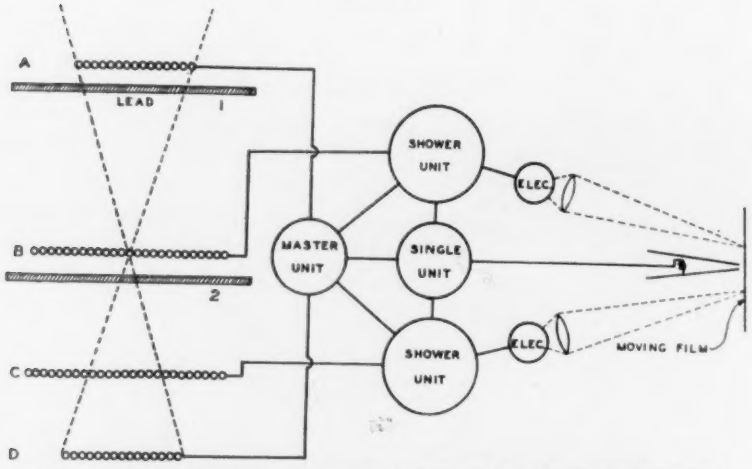
relate it to the disappearance of the soft component. It is hoped that further experiments will elucidate this point.

While the foregoing observations were being made, and through the aid of a grant from the American Association for the Advancement of Science, for which I desire here to express appreciation, I also made some observations in the mine, using an apparatus devised by Mr. W. E. Ramsey and myself, and in which the showers corresponding to from two to seven rays passing through the apparatus were recorded. The

apparatus is shown diagrammatically in Fig. 7, and Fig. 8 is an actual picture, the captions giving an outline of the method employed. The essential element was the utilization of horizontal trays of counters designed to measure the number of rays emerging in shower form from layers of shower producing material placed above them. In each case, it was the shower production in lead which was studied.

It was found that the showers of all sizes between two and seven rays as measured by our apparatus decreased from sea-

FIG. 7.



A, *B*, *C*, and *D* are the counter trays. 1 and 2 represent lead plates. The master unit was designed to prevent any of the other units from operating unless at least one counter in each end-tray discharged. The section marked "single unit" recorded the number of occasions on which at least one counter in each tray discharged. The shower units operated electroscopes which gave deflections increasing with the number of counters which discharged in the corresponding trays to which they were connected. The images of the electroscope fibers fell upon a slit behind which was moving photographic paper. The operation of the single unit caused the center part of this slit to be illuminated in a path which did not overlap the electroscope records.

level to the 100 foot depth in about the same proportion, and in a proportion equal to that representative of the decrease of the measured cosmic-ray intensity itself.

Since the hard component is dominant at and below sea-level, one is naturally tempted to believe that shower phenomena at such depths are attributable to it. The foregoing parallelism is in harmony with this view; and, indeed, it is difficult to see how one can avoid attributing the showers in question to the hard component for, if we were to assume

that they were the progeny of electrons which had entered the atmosphere from outside, it would be necessary to assume unbelievably high energies to account for a measurable progeny in the form of showers at a depth of 100 feet below the earth's surface.

Further Matters Concerning Showers Initiated by the Hard Component.—Experiments based on measurement of absorption of cosmic-rays by lead in cloud chambers have given

FIG. 8.

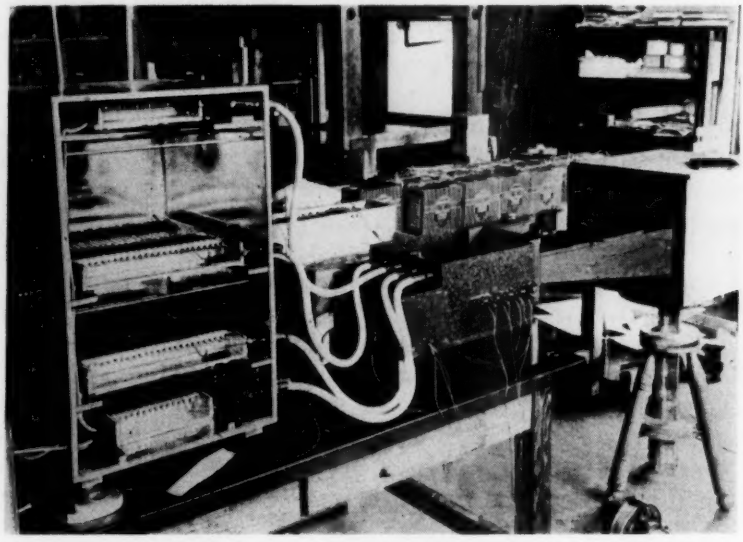


Photo by Steinmetz.

The large box at the left contains the trays and the lead plates. This box leads, through the rubber cables shown, to the black metal box which contains the master unit, single unit, shower units, and electroscopes. At the extreme right of the picture will be seen the camera, supported on the wooden tripod.

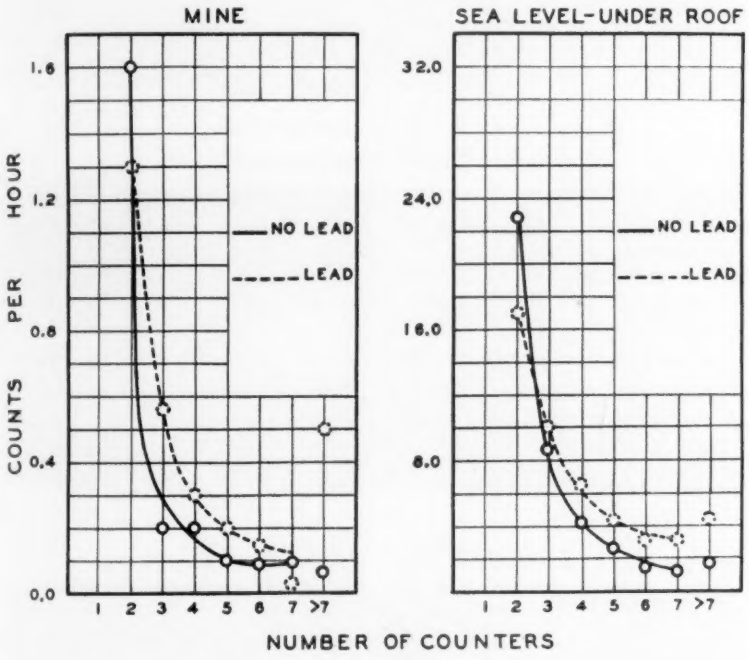
evidence of very small absorption for the hard component as compared with the absorption for electrons. In line with the foregoing conclusions, however, it is necessary to suppose that the hard component rays do occasionally give rise to progeny, as do the soft component rays, and it is natural to suppose that these progeny may be of the electron type. If this were the case, we should expect the passage of a hard component ray through matter to be a phenomenon in which, on rare

occasions, it gave rise, possibly among other things, to high energy electrons. In this act it itself might disappear, or it might continue on, repeating the story at rare intervals. In either case we should have, accompanying the hard component rays, electrons of high energy which had originated in the matter through which the hard component rays had passed. These electrons would give rise to progeny according to the same principles as would the soft component primary electrons. It is, therefore, of interest to inquire whether those particles which we observed as shower particles in the mine have, in actuality, the characteristics of electrons. To this end, we analyzed our results as regards the story they gave in the matter of growth of the shower phenomena in lead.

Referring to the captions of Fig. 7 and 8 for the description of the apparatus, it will be recalled that the shower measuring units were only allowed to operate when some ray passed through that telescopic system whose angular limits were defined by the two end-trays. Such a passage of a ray through all four trays we shall call an "event." Corresponding to each event, the number of shower rays emerging from a plate A, 0.6 cms. thick, was measured, as was also the number of shower rays emerging from a similar plate B placed below it. It was found that the ratio of the total number of shower rays emerging from B to the number emerging from A was 1.3, where, by the number of shower rays in each case, we mean the number of rays in excess of the number of single rays which are always associated with any recorded event. We may now ask what the average energy of a group of electrons would have to be in order that, through the processes of the quantum theory, the electrons would result in the production of showers in lead such as to give the ratio 1.3 already cited. The answer is 2×10^8 e.v. So far, nothing has been proved because the theory enables us to calculate the corresponding energy, whatever ratio we assign. The energy having now been determined, however, we may ask how many of such electrons would have to enter the piece of lead A per hour in order to produce on emergence from that piece of lead the number of shower rays found in one hour. The answer is seven. This is approximately equal to 7.5,

which represents the difference between the total number of rays recorded per hour in the absence of the lead, and the number of events recorded. Thus, there is harmony between the experiments, and the assumptions that the hard component rays do not produce in measurable numbers showers in the lead, but that they are accompanied by shower producing electrons of energy equal to about 2×10^8 e.v.

FIG. 9.

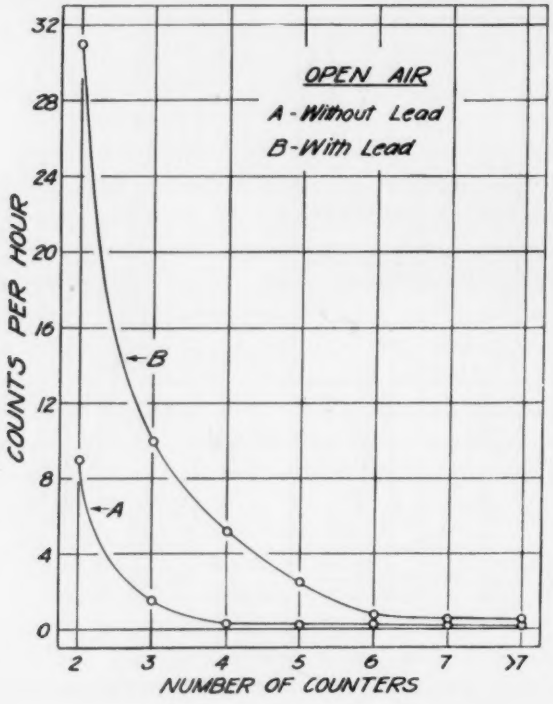


Although, therefore, in harmony with the above considerations, the hard component does not produce showers in measurable quantity in the thicknesses of lead used in our experiments, we must, nevertheless, assume that it is the showers produced by the hard component in the great thicknesses of the earth's substance which, in actuality, represent the electrons found in the mine. In other words, it is natural to regard the hard component shower phenomenon as one occurring at rare intervals, but possibly with the ejection, on

these occasions, of electrons or of electron producing rays. The resulting electrons, through the ordinary quantum theory processes, may then be regarded as constituting or as giving rise to such shower producing electrons as are to be found in the mine.

In Fig. 9 are plotted horizontally the sizes of showers as measured by the number of rays recorded for each shower;

FIG. 10.

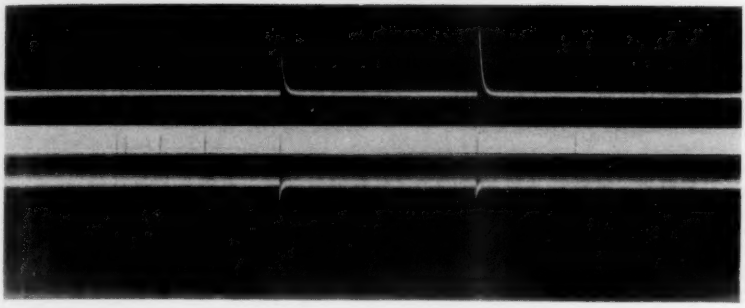


and vertically are plotted the numbers of such showers occurring per hour. The data with and without lead are given, and two graphs are shown, one for the surface of the earth (in the attic of our Swarthmore laboratory) and one for the observations in the mine, the thickness of the lead being in each case 12 cms. Here the showers presumably originate in the material of the roof of the mine or in the material in

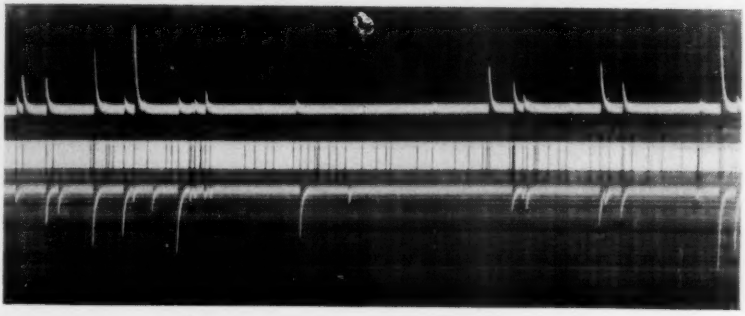
FIG. 11.

TYPICAL HALF HOUR RECORDS

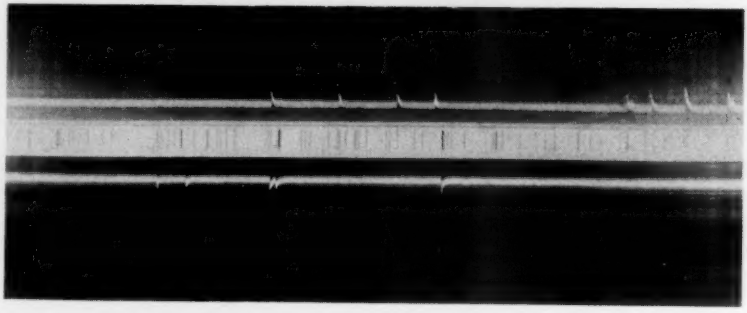
IN MINE



SEA LEVEL - UNDER ROOF



SEA LEVEL - OPEN AIR



The pictures are almost self-explanatory when taken in conjunction with the caption to Fig. 7. The electroscopes deflected suddenly on application of the impulses and then returned to their zeros by leakage through high resistances. This accounts for the peak-like structure in the records. The heights of the peaks determine, through calibration, the number of rays in a corresponding shower, allowance being made for the inefficiency factor of the counters. In the originals the tops of the peaks can be read without difficulty.

the roof of the laboratory, as the case may be. It may be added that in the measurements in the attic of the laboratory a thickness of about 10 cms. of marble was placed over the apparatus to duplicate the conditions in the roof of the mine. Figure 10 shows corresponding curves taken on the roof of the laboratory with nothing but a thin canvas covering over the apparatus. The detailed significance of these curves will not be discussed here.

Figure 11 shows the kind of traces which were obtained with the recording apparatus. The peaks indicate the showers, the black lines across the center indicate the events above referred to, and further details are given in the captions.

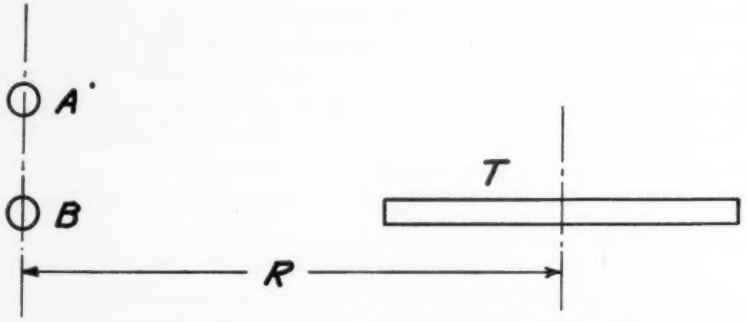
Simultaneity in Cosmic-Ray Phenomena.—The shower phenomena existing in the absence of lead present interesting questions. Thus, by adding up all of the different rays obtained in different showers, it is possible to inquire how many rays, on the average, accompany any event within the limits of our recording apparatus. The results in the mine indicated that, on the average, ten events were accompanied by an additional six rays. The information obtained in this way is subject to some ambiguities as to its interpretation; and into these I will not, for the moment, enter. A fundamental problem of rather vital significance becomes, however, raised and may be cited in the following form:

Suppose that we had an apparatus capable of measuring the rays over a very large area, an infinite area in the limit. Concentrating our attention on any one ray which, at the moment, is passing through the area, we may inquire how many other rays are passing through that area simultaneously with it. The interest of this story, of course, lies in the fact that if a large proportion of the radiations which we measure as cosmic-rays are of shower origin, those rays which come from an individual shower should be simultaneous in their passage through any plane below the origin of the shower. Even if a primary ray should produce secondaries all along its path, and if these secondaries should be inclined at angles to the primary, so that their times of passage through an assigned horizontal area were different, those differences in time woud be negligible within the limits of resolution of our apparatus, since the rays travel with velocities com-

parable with the velocity of light. An examination of the simultaneity of different measured rays contains, therefore, information as to their shower origin. This matter was referred to in my report of April 1936, and since that time we have made various investigations having a bearing upon the subject, including the mine experiments referred to. At the present time, Mr. Ramsey and I are carrying out an investigation of the matter in a manner designed to eliminate as far as possible many of the disturbing elements concerned with it. In principle the procedure is as follows:

We have a Geiger Counter telescope AB, Fig. 12, and we have an area T of Geiger Counters which can be placed in any

FIG. 12.



position in relation to AB, and which is so arranged in relation to its accompanying electrical equipment that it is allowed to operate only when a ray goes through AB; and, under these conditions, it records the number of rays which pass through it simultaneously. By making measurements with this area of counters at varying distances from AB, and by suitably integrating the results for any distance over the circular ring which the counter area would describe if rotated around AB as axis, we can obtain for the whole infinite horizontal plane extending out from AB the average number of singles, doubles, or triples, etc., passing through the area for any number of assigned rays going through AB. To cut a long story short, we can inquire how many rays on the average pass through the infinite plane simultaneously with any one ray passing through AB.

We have extended our observations up to distances comparable with 150 cms. from AB; and even at these distances there are occasionally rays which occur simultaneously with rays through AB. Confining our attention to no more of the infinite plane area than is comprised by the 150 cms. radius aforesaid, we find that a ray through AB, and therefore in general any other ray, is accompanied, on the average, by 0.5 other rays in the space around.

The extension of the simultaneous rays to such large distances from AB is difficult to harmonize with the belief that each simultaneous group originates in a single center in the roof material in the attic, since this material is only about five feet above the apparatus. One is led to think of their originating at much greater vertical distances in the atmosphere itself. One is led to think of their representing progeny of a single event associated with the entry of a primary electron into the atmosphere, in which case they form constituents of what we know as the soft component. Another supposition is that they represent particles emitted along the path of a hard component primary. Such particles would arrive, to all intents and purposes, simultaneously at the plane of observation.

The view that the simultaneous rays here considered form part of the soft component progeny encounters difficulty from the fact that the sizes of the showers developed in the roof of the attic are such as to suggest that the electrons responsible for them have energies of an order of magnitude between 10^9 e.v. and 10^{10} e.v.; and for such energies we must look to some other source. The only obvious source available is the hard component.

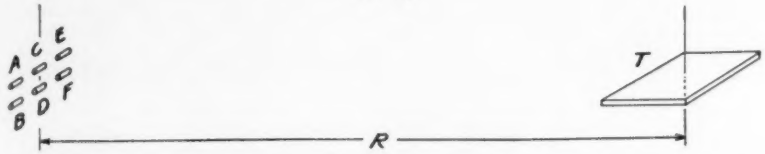
Suppose, therefore, that a hard component primary experiences β times, per unit of path, an "event" in which it emits a secondary with an energy of 5×10^9 e.v. The average angle of divergence of such a secondary from the original path of the primary is of the order 1.4×10^{-2} radians,[14] so that the path of the primary which contributes secondaries to the circle of radius 1.5 meters is about 100 meters of air, or 0.1 meter of water equivalent. The number of such rays falling

[14] W. Heisenberg, *Annalen der Physik*, **13**, 430 (1932); see also W. F. G. Swann, JOUR. FRANK. INST., **220**, 373 (1935).

within the circle of 1.5 meters radius will be 0.1 β. If the rays experienced, in the 1 foot concrete roof, multiplication such as would be characteristic of electrons of energy 5×10^9 e.v., we should expect, within the aforesaid circle, below the roof, about 0.4 β shower rays as corresponding to one primary ray.[15] Equating this to 0.5, the experimental value already cited, we obtain $\beta \sim 1$. In other words, the results are in harmony with the view that, associated with the hard component, there are losses of the order 5×10^9 e.v. occurring in the atmosphere, with a frequency of the order 1 per meter of water equivalent path.

Incidentally, it may be observed that the invocation of relatively frequent losses of energy of large amount by the hard component renders more readily understandable than

FIG. 13.



would otherwise be the case the production of such very large showers as are occasionally observed.

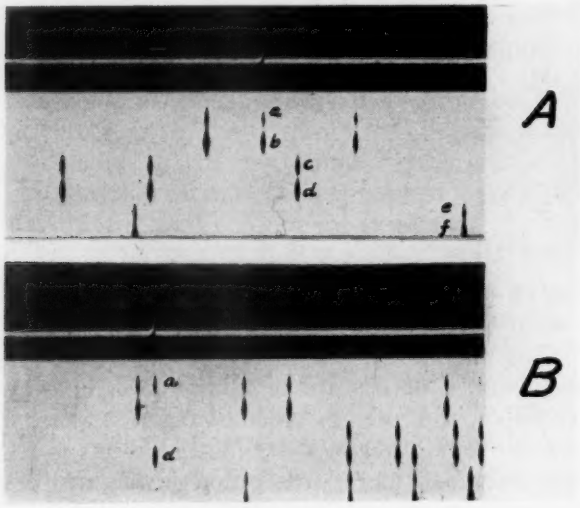
The main purpose of the foregoing discussion is to show that the existence of a state of affairs in which, below the roof, there is on the average at least 0.5 ray which is simultaneous with every other in a 1.5 meter radius, is a situation which is in harmony as regards order of magnitude with the thought that the secondaries in question arise ultimately from particles emitted with considerable energy and frequency by the hard component. An attempt to explain the origin of these rays as arising in the soft component would meet great difficulties in accounting for the number, and insuperable difficulties when attempt was made to apply it to our data for the mine.

At first sight, it might be thought that the mechanism we have envisaged would result in there being about 1.5 times the measured cosmic-ray intensity below the roof as occurs above it. This is not so, however, for the roof also performs

[15] H. J. Bhabha and W. Heitler, *Nature*, **138**, 40 (1936).

the function of eliminating the lower energy electron rays which enter it above, and which, in its absence, would have reached the apparatus below. The elimination of these rays more than counteracts the addition of the shower rays which have been referred to so that the net result is a diminution in the over-all measured intensity. The story here is quite analogous to that encountered in the ordinary quantum theory of secondary production by electrons in the atmosphere, and according to which, in spite of what would be an increase in the number or rays with depth of penetration in the absence

FIG. 14.



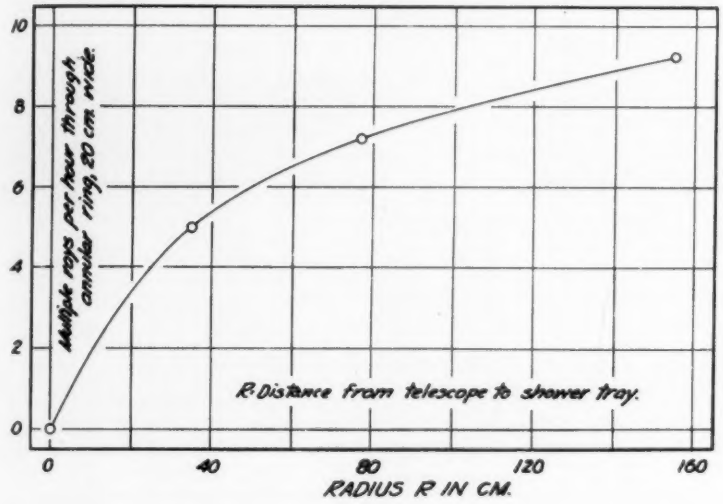
of ionization loss, there is, in actuality, a decrease with penetration after a sufficient depth is attained.

It may be stated that the counter telescope AB referred to in the foregoing discussion was, in actuality, replaced by three independent telescope sets, Fig. 13, so as to enhance the rate of accumulation of results. The arrangements of the elements of these telescopic units was such as to prevent the operation of the shower measuring set except when a ray passed through one of the upper members of the telescopic units and one of the lower members. However, since the desire was to confine attention to rays which passed only

through the individual members of the same telescope, some means for eliminating such rays as would pass through C and B, for example, was necessary.

To this end every counter which discharged was allowed to record, provided that at least one member of the top set and one member of the bottom set discharged simultaneously, and no counter was allowed to record unless this happened. The records were made by means of light spots, one corresponding to each of the six counters. Thus, for example, in the trace in Fig. 14A, the spots a, b, c, d, e, f correspond to

FIG. 15.

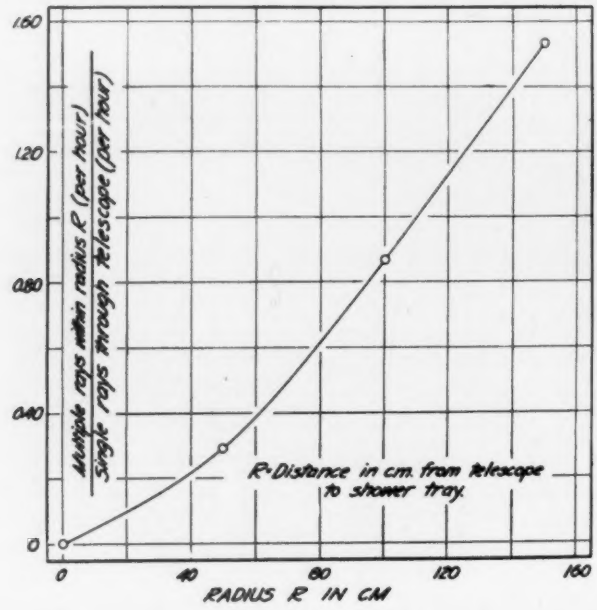


counters A, B, C, D, E, F. We have a record of a shower, and on the same record we have spots a and b corresponding to the counters A and B. We know that this is a shower corresponding to a ray which passed through A and B. On the other hand, in Fig. 14B, we have a situation which sometimes occurred. A shower is recorded, but it is associated with the dots a and d which correspond to the counters A and D, and these two counters do not form part of one vertical telescopic system. For this reason, such records were discarded.

Figure 15 is of interest in showing as a function of R, the

number of rays within an annulus 20 cms. wide and of average radius R simultaneous with the passage of a ray through one of the telescopic systems. It is of interest to note that the curve continues to rise, and at least does not approach a falling form within the limits of the measurements. In other words, as we proceed outwards from AB, successive annuli pay contributions which at least do not decrease with R. In fact, the diminution of number of rays per unit area with distance

FIG. 16.

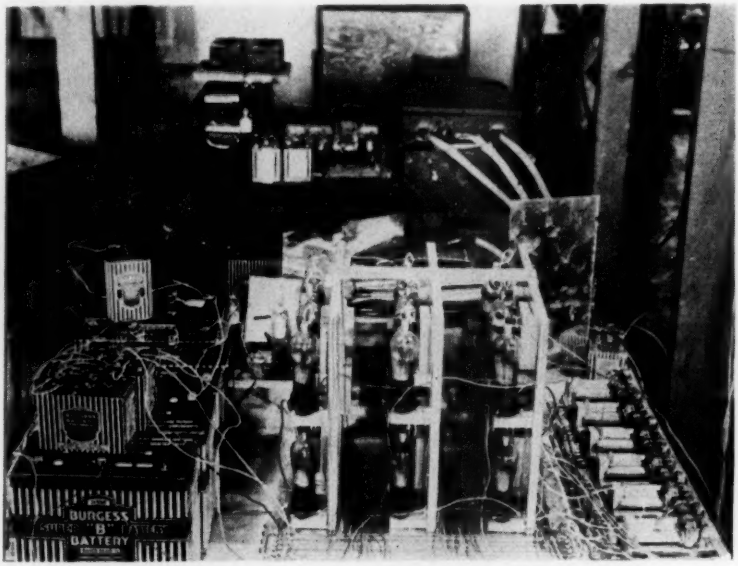


from the telescopic counter is more than balanced by the increase of area of the annulus. How far this horizontal feature of the curve extends, we do not know; and the greater the distance of its extension, the greater the number of rays which, on the average, are to be regarded as simultaneous with any one ray.

Figure 16, obtained by integration, gives, as a function of R, the total number of simultaneous rays falling within the radius R. Figure 17 is a picture of the apparatus above described.

Further Contemplated Experiments on Shower Production by the Hard Component.—Much information on the production of showers in substances like lead has been obtained from cloud chamber investigations by observers in various laboratories, the general procedure being to place in the cloud chamber a piece of lead 1 cm. or so thick and observe what

FIG. 17.



The system in the wooden frame in the foreground is the system of three telescopes. In the rear, attached to the three rubber cables, is the black box containing the electroscope and amplifying system. The counter tray is not visible.

happens as a ray enters it. Figure 18, obtained by J. C. Street and E. C. Stevenson, is typical of the results. The conclusions drawn from such experiments are to the effect that shower production is, for the most part, a function of the activities of electrons; and very little is known about shower production by the hard component itself. We have been led to infer from our experiments in the mine that the hard component must give rise directly or indirectly to electron showers, but even in this case the growth of the showers occurs, in all probability, by the electrons which are first generated giving

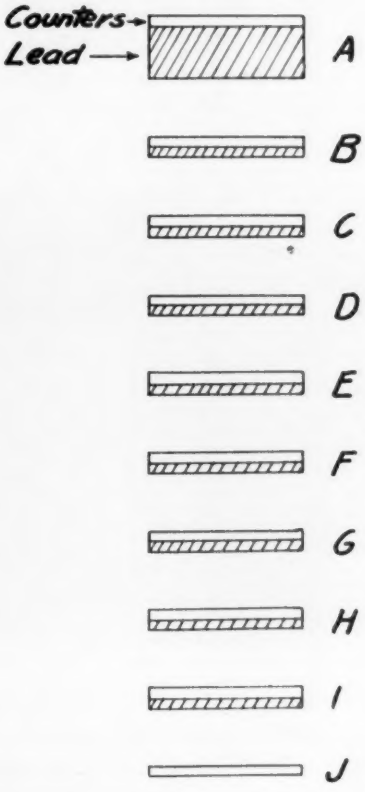
rise to progeny through the ordinary processes of electron shower production. It is extremely important to have more information upon the initial act by which a hard component ray becomes responsible for an event which ultimately grows into a shower. The difficulty of investigating this matter lies in the fact that the act in question occurs, presumably, so infrequently that one would have to deal with relatively large thicknesses of lead in order to observe it; and in this case the

FIG. 18.

phenomenon would be hard to observe if the lead were in one piece, since in general it would happen well inside, and the story of the emerging rays would be related by elements of great complexity to the initial act, elements involving all that had happened between the point of occurrence of that act and the points of emergence of the shower. For this reason, we are building an apparatus of the type represented in Fig. 19. It comprises the following parts: First, there are eight slabs of lead, *B*, *C*, *D*, *E*, *F*, *G*, *H*, *I*, each 1 cm. thick. Below each slab is an array of counters, arranged carefully in proper geometrical pattern, and with the lengths of the

counters in one layer perpendicular to the lengths of those in the adjacent layers. Above this is placed a slab *A* of lead 10 cms. thick, and above and below this another layer of counters. Under these conditions, it will be seen that it is possible for a ray falling within a relatively limited vertical

FIG. 19.



solid angle, to pass through one counter in each of the trays. There are also other avenues inclined at angles to the vertical which, through the geometrical arrangement adopted, can permit of a ray passing right through in such a manner as to affect one counter in each tray. Every counter is connected to an individual electroscope. The electroscopes form a

battery of 180 which shine spots of light upon an area the size of a photographic plate. In the first place, it is arranged that none of these electroscopes are permitted to operate unless at least one counter in each tray has discharged simultaneously. Such simultaneous discharges guarantee that the phenomena under investigation are associated with a ray which has passed through all nine slabs of lead. The number of electroscopes, associated with any layer, which give a deflection determines the corresponding number of counters in that

FIG. 20.

layer which have discharged, and so determines the number of secondary rays which have emerged from the lead laid immediately above. In this way, we have a means of tracing the initiation and growth of a shower phenomenon in the ten pieces of lead and we have a guarantee that the said shower phenomenon must have originated from hard component rays, since only such rays—with very rare exceptions—could pass through 18 cms. of lead.

It is our intention to investigate the shower producing characteristics of the hard component at sea-level and at the

equivalent of various depths below sea-level, in order to learn something about the variation of the phenomenon with the energy of the primary rays. For this purpose, and for several other purposes, we have erected a water tower, Fig. 20, in which the height of the water can be varied from zero to 30 feet—the equivalent of an extra atmosphere. The lowest segment of this tower constitutes a room, 10 feet in diameter and 12 feet high. By providing it with a metal floor we have secured, in addition to the other advantages, a room completely shielded from electrostatic disturbances. Of course, the telescopic nature of our equipment limits the rays under investigation to those which pass through the whole column of water.[16]

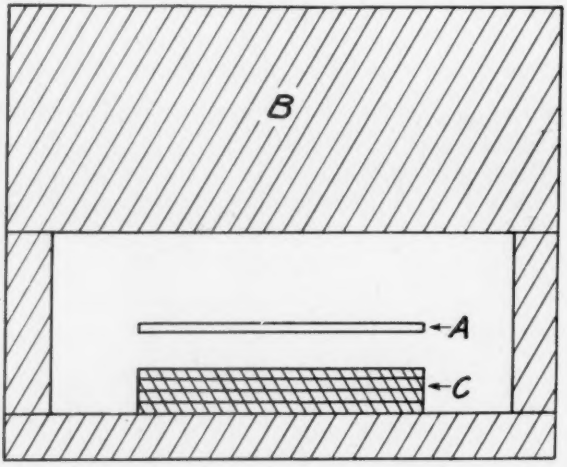
A SEARCH FOR RADIOACTIVITY INDUCED BY COSMIC-RAYS.

One of the chief subjects of investigation in atomic physics at the present time is the investigation of radioactivity induced in matter by high energy particles. This, of course, suggests the possibility of the production of radioactivity by cosmic-rays. A little consideration involving a comparison of the efficiency of production of radioactivity by high energy rays generated in the laboratory immediately casts some doubt upon the possibility; but since the cosmic-rays have much

[16] At this point an experiment illustrating the shower phenomena, and incidentally some of the principles of the apparatus just referred to, was shown. In this experiment there were 25 counters, each about 20 cms. long. Every counter was provided with its customary coupling condenser and leakage resistance. The plate of the condenser remote from the counter was coupled to the moving element of an electroscope through a neon tube. Electrical circuits were arranged so that when, and only when, more than one counter discharged, a momentary bias was put on the common case of all the electroscopes lowering the potentials of their moving systems momentarily. During this momentary period any counter which discharged did so through its neon tube into the corresponding electroscope. The electroscope, of course, deflects comparatively slowly and then returns to its zero by discharge through a suitably chosen resistance. The momentary pulse on the case of the electroscopes produces no deflection unless accompanied by an actual discharge of electricity into the electroscope through the neon tube. Each electroscope is provided with a mirror which reflects a beam of light upon a screen, so that as the apparatus was watched, it occasionally showed streaks of light upon the screen, the number of streaks corresponding to the number of shower rays which, at that instant, had passed through the electroscope system.

greater energy than the highest energy particles of laboratory production, and since the efficiency of the production of radioactivity increases with the energy, it seems not entirely unreasonable to look for induced radioactivity resulting from cosmic-rays. It had, in fact, occurred to a European investigator to seek for induced radioactivity as the result of cosmic-rays and such induced radioactivity was reported as found, and in such amount as apparently to account for something of the order of 50 per cent. of the ionization customarily attributed to the direct action of cosmic-rays. In view of

FIG. 21.



the extreme importance of such a conclusion, if substantiated, it seemed highly desirable that the verification of this result should be attempted; and, to this end, Mr. W. E. Ramsey and Dr. and Mrs. Montgomery [17] performed an experiment which may be described briefly as follows:

The apparatus is diagrammatically represented in Fig. 21. First, we have a layer of 25 counters *A* which served as the indicator of the radiations passing through the area which they occupied. The electrical system connected with these counters is not shown. The counters were surrounded by a

[17] W. E. Ramsey, C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, **53**, 196 (1938).

lead housing 5 cms. thick on the sides and bottom, together with a lead slab *B* placed on the top. Five centimeters of lead was sufficient to shield the apparatus from the ordinary radioactive rays resulting from radioactive contamination of the surroundings. The lead slab over the top of the apparatus was in the form of miscellaneous pieces of lead to an effective thickness of 25 cms., that is, a thickness sufficient to produce an easily measurable change of cosmic-ray intensity by absorption. In addition to the foregoing, there was a piece of iron, *C*, 5 cms. thick, and of the same horizontal area as the counter tray. Its thickness was made up of four slabs; and this was the material in which the possible production of induced radioactivity by cosmic-rays was sought. The four iron slabs were first spread out in a horizontal plane outside the apparatus, and allowed the opportunity to acquire, under the influence of the cosmic radiation, such radioactivity as might come to them under these circumstances. Also, while these plates were outside the shield, the cosmic-ray intensity was measured with the counters. The four iron plates were then put one on top of the other and were placed inside the shield under the 25 cms. of lead. Under these conditions, had there been in the iron any radioactivity resulting from cosmic-rays, we should have expected that radioactivity to decay at a rate determined by the natural decay period of the radioactive substance to a new value characteristic of the cosmic-ray intensity under the 25 cms. shield. Such a phenomenon would have resulted in a variation in the counting rate of the counters during the time of decay,[18] and such variation in the counting rate of the counters would have been symbolic of and would have provided a measurement of the induced radioactivity produced by an amount of cosmic radiation equal to that absorbed by the 25 cm. shield of lead.

If the radiations from the supposed radioactive substance are of the gamma ray type, we obtain conclusions most favorable to the supposition of induced radioactivity by supposing them to have the largest possible range; for, in this case, one can argue that the thickness of iron used, being less than that used by the former investigators, might give a

[18] The half period of decay reported by the former investigators is 8.6 minutes.

smaller effect than that obtained by them. Assuming the maximum range permitted by theory and supported by experiment for gamma rays, we conclude that the 5 cm. slab would contribute 75 per cent. of the gamma radiation which would be contributed by an infinite slab uniformly activated. A radioactive radiation of the beta ray type would, in a very small thickness of iron, be converted into gamma ray radiation, so that the ultimate story for beta rays amounts to the same as that for gamma rays.

The final conclusion then is to the effect that any induced radioactivity produced in the present experiments amounted to less than one-sixtieth of that formerly reported.[19] One could harmonize the present experiments with those formerly reported by the assumption that the radioactive radiations under discussion were of the alpha particle type. However, such an assumption must be discarded for various reasons.

HIGH ALTITUDE WORK AND ALLIED PHENOMENA.

Frequently, in former reports, I have had occasion to refer to the influence of the earth's magnetic field in controlling cosmic-ray phenomena. Speaking briefly, the earth's magnetic field hinders the entrance of charged particles into our atmosphere from outer space, the hindering effect increasing from magnetic polar to magnetic equatorial regions. The net result is that at any latitude and longitude there is a minimum energy for entry (the minimum depending upon the zenith angle and azimuth) and this minimum diminishes as we go from equatorial to polar regions. It is known that the cosmic-ray intensity at sea-level increases with increase of magnetic latitude up to about 42°, and then remains constant. If all of the rays which enter the atmosphere could penetrate it, we should expect the increase with latitude to progress from the magnetic equator to the magnetic poles. The customary explanation of the cessation of the increase beyond

[19] Since the present investigation by Mr. W. E. Ramsey and Dr. and Mrs. Montgomery was published (*Phys. Rev.*, **53**, 196 (1938)) the results of the experiments formerly recorded as giving evidence of induced radioactivity have been found by the authors of the investigation to be attributable to other and purely instrumental causes. On the basis of further experiments, however, they still hold to a belief in the existence of the effect.

42° has been to the effect that the additional rays which could enter the atmosphere in these regions would not have enough energy to penetrate the atmosphere to the earth's surface. On this explanation one would expect to find the increase of cosmic-ray intensity with latitude to continue beyond 42° right up to the magnetic poles, provided that the observations were taken at sufficiently high altitudes. Observations on the variation of the latitude effect with altitude are not very consistent. Some observers have found the increase of intensity to extend beyond 42°, but Cosyns, working in Europe, found the cessation of increase to occur at 42° for all altitudes at which observations were taken. This fact has given rise to a theory by M. S. Vallarta to the effect that it is the sun's magnetic field which is, in actuality, operative in determining the cessation of increase with magnetic latitude at 42°. In fact, Vallarta's theory is to the effect that the sun's magnetic field excludes from the whole region around it, or at any rate from that in the plane of the earth's orbit, particles whose energies lie below a certain fixed limit. The theory of the latitude variation then becomes one in which the increase with magnetic latitude proceeds according to the old theory until 42° is reached, but in which further increase in the sea-level intensity is prevented, not by atmospheric absorption, but by the fact that the sun cuts out particles of energy below that which can just provide for entry at 42°. According to this view, there should be no increase of intensity with magnetic latitude beyond 42°, even in the highest regions of the atmosphere while, according to the older view, the increase with latitude should continue at high altitudes from magnetic equator to magnetic poles.

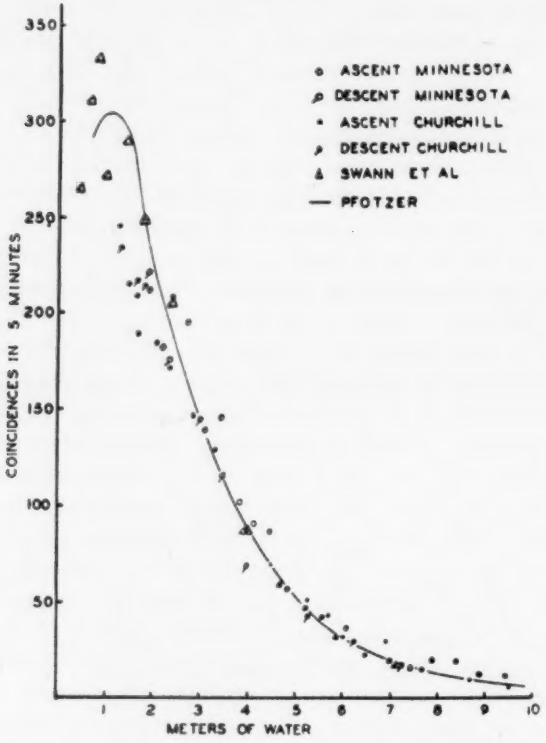
For the specific purpose of testing the foregoing alternatives, as well as for the general accumulation of information on the variation of intensity with altitude and latitude, Dr. T. H. Johnson made a trip last summer with the apparatus which has been descrbed on several occasions in former reports, for the purpose of investigating the variation of cosmic-ray intensity with altitude, more particularly in latitudes approximating to the magnetic pole.

As formerly descrbed,[20] the apparatus comprised a counter

[20] T. H. Johnson, JOUR. FRANK. INST., **223**, 339 (1937).

telescope which was carried aloft by a battery of hydrogen filled rubber balloons and which transmitted its signals by radio, so that on a ground station it was possible to record simultaneously, the passage of the cosmic-rays through the

FIG. 22.



counters, the barometric pressure and the temperature of the apparatus.

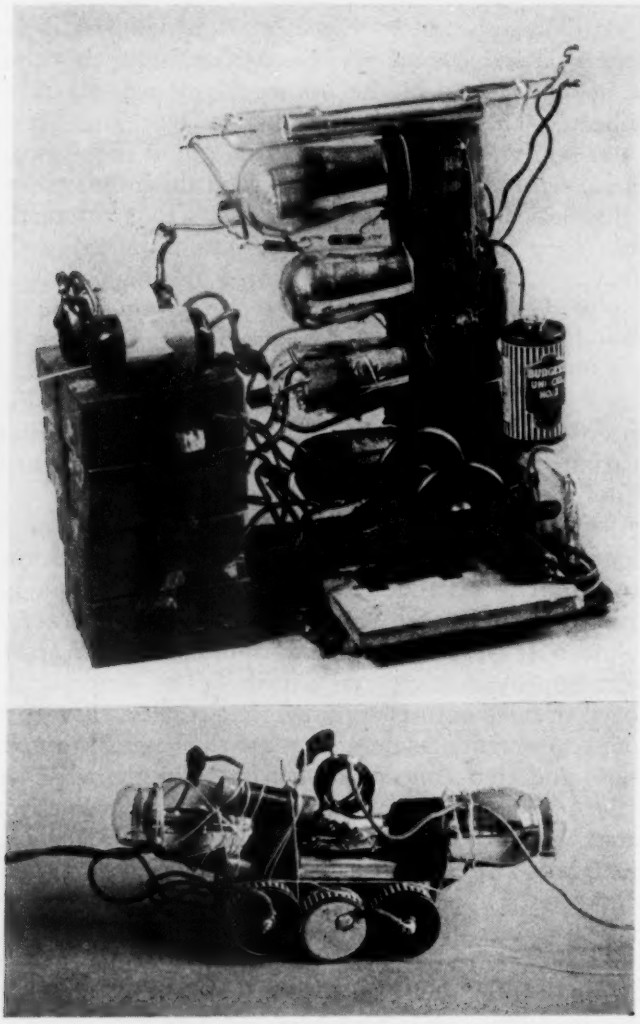
Observations were obtained in northern Minnesota, and at Churchill, Manitoba, at a station within about 20° of the magnetic pole. The expedition is indebted to the courtesies extended by the Department of Conservation of the State of Minnesota through the good offices of Director G. M. Conzet, and to Dr. J. Patterson of the Canadian Meteorological Service. Financial support has also been given by the

Carnegie Institution of Washington. About a dozen flights were made, of which fifty per cent. gave significant data. These data are shown in Fig. 22, in which the ordinates represent relative cosmic-ray intensities, and the abscissæ depths below the top of the homogeneous water equivalent atmosphere. The results show that at depths greater than two water equivalent meters below the top of the atmosphere there is no significant difference between the intensities at 70° north magnetic latitude and 54° north. It is interesting to compare these results with the results obtained with our large battery of cosmic-ray telescopes during the National Geographic U. S. Army Air Corps Stratosphere flight, and extended by the same apparatus to lower altitudes in our airplane flights made with the coöperation of the U. S. Army Air Corps. The data in question are also shown in Fig. 22. It is interesting to add the results deduced from G. Pfotzer's observations taken in flights from E. Regener's laboratory in Germany. These are shown by the full line.

Dr. Johnson is continuing the investigations on these matters with the object of securing greater precision and greater extent of latitude. With this plan in mind, and in coöperation with Dr. S. A. Korff, who is now working with Dr. Johnson at the Bartol Foundation, the former apparatus has been improved in several details. The program has, in fact, been divided into two parts, that concerned with directional measurements, as heretofore, with a cosmic-ray counter telescope, and that concerned with measurements depending upon the integrated effect of the cosmic radiation from all directions and obtained with a single counter. It is particularly in relation to this project that Dr. Korff is coöperating. In both types of apparatus batteries have replaced the former mechanical means of generating the potentials operating the counter sets. Improved forms of barographs have been devised and employed; and relatively large counters are employed which, under ordinary conditions, would in the stratosphere record too many cosmic-ray impulses to permit of automatic recording, but whose impulses are scaled down in number for recording in such a manner [21] as to render automatic recording possible while retaining the important feature

[21] T. H. Johnson, *R. S. I.*, **9**, 218 (1938).

FIG. 23.



The tube at the top of the upper figure is a single Geiger counter and below it is a circuit for scaling down the count. Every twenty-fifth cosmic-ray operates a relay (not visible in the picture) and this keys the radio device (lower photograph) which transmits the data to a receiving station in the laboratory. In the foreground is a barograph which also keys the radio device in a manner to indicate the barometric pressure at 20 second intervals throughout the flight. Batteries for the operation of the Geiger counter, the circuit, and the radio transmitter are shown at the left of the upper figure, and the filament battery appears at the right. For photograph of balloons, see last year's Report of the Director of the Bartol Research Foundation, JOUR. FRANK. INST., 224, 417 (1937).

of eliminating statistical fluctuations by the utilization of a large rate of reception of impulses. Figure 23 represents a picture of the apparatus, and the relevant details are described in the legend.

I have here an experiment for the purpose of indicating the function of the scaling circuit whose purpose is to enable a large number of impulses received at random to be averaged in such a manner that an actual record is made, for example, for every ten, every hundred, or every thousand counts received. The purpose of the experiment is to illustrate how the perfectly random nature of the individual impulses is integrated into a series of records which are very evenly spaced in time.[22]

Dr. Johnson and Dr. Korff have recently made several flights from Swarthmore with the new apparatus referred to. The results of one flight are shown in Fig. 24.

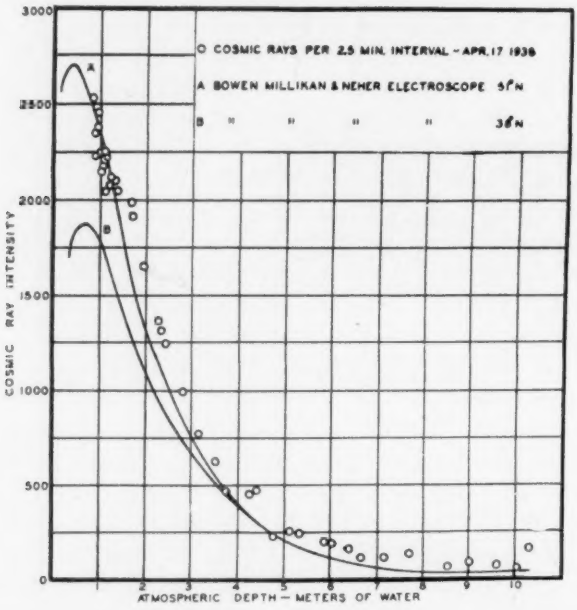
The experimental points were obtained with the scaling circuit described above on a balloon flight sent up in Swarthmore on the night of April 17, and it is of interest to note that whereas each point represents the number of cosmic-rays incident in a two and a half minute interval, the actual number of rays involved is of the order of 2000 and the accuracy is determined by the chance variations in this large number of rays. Previous measurements of this type have been limited in their accuracy by the fact that it has not been possible to transmit successfully and record more than about one-tenth this number of rays in a similar time interval.

The flight of which the results are illustrated in the figure is of special interest since the apparatus was in the stratosphere during the most intense magnetic storm of the century. Such magnetic storms have been found to reduce the cosmic-ray intensity at sea-level by two or three per cent., and it has been suggested that this reduction is caused by an increase in the earth's magnetic moment during the storm with a consequent increase in the blocking effect of the earth's field for the

[22] The experiment involved the use of radium as the source of the counter impulses. These impulses were recorded directly upon an oscillograph so that the statistical nature of their reception could be observed. On another part of the screen of the oscillograph, the records of the reception of each twentieth ray appeared, with considerable time regularity.

lower energy radiation. If this suggestion is the correct explanation of the sea-level effect, one would have to expect that the entire curve representing the cosmic-ray intensity versus atmospheric depth would change to correspond with what is found under normal conditions at a more southerly latitude where the sea-level intensity is reduced by a corresponding amount due to the normal latitude effect. The change to be expected is illustrated by the curves *A* and *B*

FIG. 24.

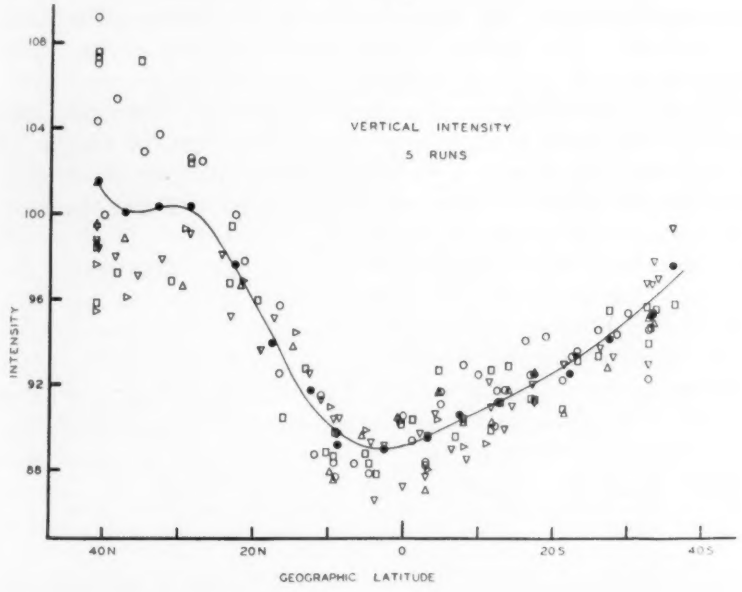


which represent the intensities measured by I. S. Bowen, R. A. Millikan and H. V. Neher [23] at 51° magnetic north and 38° magnetic north respectively. Although the data obtained during the storm do actually appear to deviate from the curve *A* in the direction to be expected, part, if not all, of the difference can be accounted for by the difference in the measuring technique and the final conclusion regarding the effect of the storm must await further measurements under normal magnetic conditions.

[23] I. S. Bowen, R. A. Millikan and H. V. Neher, *Phys. Rev.*, **52**, 80 (1937).

Sea-Level Latitude and Seasonal Variations.—In former reports I have referred to Dr. Johnson's measurements of variation of intensity with latitude at sea-level. Figure 25 is a curve which was shown in my report last year, and in which the vertical intensity as measured by a cosmic-ray counter system is plotted against the magnetic latitude. The point with which I am concerned at the moment is the rather wide variation, about 4 per cent. of the total cosmic-ray intensity, in the data at the higher latitudes, a variation which is greater

FIG. 25.



than can be accounted for by inaccuracies of observation. A recent, more careful examination of the data has shown that the higher values of the intensity correspond to observations obtained during the winter months, while the lower values correspond to the summer. There has been a discrepancy in latitude observations in the data of other observers. Thus, for example, the latitude variation obtained by R. A. Millikan has been markedly lower than that obtained by A. H. Compton. Both of these sets of observations showed

the same variability at high latitudes as do Johnson's; and again this variability seems to be associated with the period of the year when the observations were taken.

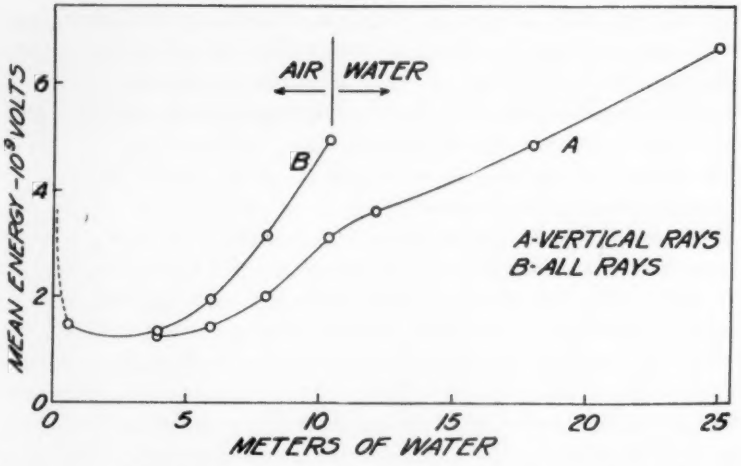
If we believe the Vallarta theory already referred to, there would be some grounds for expecting seasonal variations of cosmic-ray intensity at latitudes in the neighborhood of 42°, which, on Vallarta's theory, is the region where the intensity is very sensitive to fluctuations in the energies of the rays which would be allowed to enter under the control of the sun's magnetic field. The expected variations would result from the variation of the earth's distance from the sun during the description of its orbit, and possibly upon other considerations. The mutual relationships of these various considerations and their consistency is not, at the present time, very well established. Taken all together, however, and without the invocation of any particular form of theory as a necessity, it seems obviously worth while to look more carefully for what has been looked for many times in the past, a seasonal variation in the cosmic-ray intensity. To this end, and also for a more complete test of the apparatus which Dr. Johnson has used for the latitude observations, he has now set that apparatus into continuous operation in Swarthmore with the object of seeking for any variations which may exist. Fortunately, this latitude is one in which considerations from the sun's magnetic field might be expected to have significance; and, moreover, it is in the range of latitudes in which the variations above referred to have been observed.

FURTHER THEORETICAL INVESTIGATIONS.

Variation of Cosmic-Ray Energy with Depth.—In spite of the complexity of cosmic-ray phenomena, and of the natures of the entities which go to make up the rays, it is safe to assume that all the rays lose their energy ultimately in the production of ionization, and the allied phenomena of excitation of atoms, that is, the delivery to the atoms of small quantities of energy which are not sufficient to produce ionization but which become ultimately radiated and lost as heat. Since the excitation loss is proportional to the ionization loss, and since the total energy loss associated with the production of one ion is known, it is possible, by measuring

the total ionization produced by the cosmic-rays below any horizontal plane, to determine the energies of the rays which pass through that plane. Then, by dividing this quantity by the number of rays, we can determine the average energy of the rays. The ionization produced below any assigned level can, of course, be obtained by integrating the results obtained for the ionization produced in a vessel by the cosmic-rays at various depths below the assigned level in question. It occurred to Dr. and Mrs. Montgomery to utilize the foregoing principles for the determination of the average energies of the cosmic-rays at different depths.[24] The results are shown in Fig. 26; and the significant thing is that the average energy

FIG. 26.



increases with the depth. This apparently paradoxical conclusion results from the fact that, although the rays lose energy as they pass through matter, there is a distribution of energy in the rays themselves, and the low energy rays become sifted out so rapidly in relation to the high energy rays as to give the latter the dominant influence in determining the average energy at the greater depths. In spite of the fact that the high energy rays lose energy in reaching these depths, the average which they now control is greater than the average obtained at smaller depths, where they had

[24] C. G. Montgomery and D. D. Montgomery, *Phys. Rev.*, **53**, 193 (1938).

greater energy but where the average was controlled in greater part by their brethren of lesser energy who fell by the wayside in the journey to the great depths.

As a corollary to the foregoing investigation, Dr. and Mrs. Montgomery, having determined the average energy of the rays at sea-level, compared it with the average energy of the rays as obtained from cloud chamber measurements. It is true that in cloud chambers there are some rays of energy too great to measure; but their number is too small to affect the average appreciably, and the net result is that the average energy calculated for sea-level by the procedure aforesaid comes out equal to that obtained from the cloud chamber measurements to within the accuracy of the observations themselves. Incidentally, this result establishes the conclusion that the energy in those components of the cosmic-rays, such as photons, which do not ionize directly, is negligible at sea-level. The reason is that while such rays would not be observed in cloud chambers, their energy, nevertheless, must ultimately become converted into ionization energy through intermediate drastic acts in which these non-ionizing entities suffer conversion to other forms.

A further point of interest concerning this matter arises from the fact that if, at sea-level, all of the radiation were of the soft component type and had arisen through the mechanism of creation of progeny in the manner already indicated, half of the energy at sea-level should exist in the photon form. The fact that this is not so is consistent with what, of course, has for long been inferred from other considerations, the conclusion that most of the cosmic-ray intensity at sea-level is attributable to entities other than those representative of the progeny aforesaid, that it is attributable, in fact, to what we have called the hard component of the radiation.

The Number of Primary Cosmic-Rays and their Energy Distribution.—It is of fundamental interest to know the number of primary cosmic-rays entering the atmosphere and the distribution in their energy. If the rays were simple entities which had entered the atmosphere from outside and had resulted in a gradually decreasing intensity with descent, we could infer the entering number by an extrapolation of the intensity depth curve obtained from regions where

measurements have been made. However, the complexity of the relationship between what is measured and what enters, resulting from the creation of progeny, as already described, prevents the adoption of such a procedure. The very existence of a maximum to the cosmic-ray intensity at a finite altitude is evidence that such a procedure would be meaningless. For this reason, other methods of attack must be adopted. I will describe a method which has been adopted by Dr. T. H. Johnson.[25]

By integrating the ionization depth curve from infinite depths to the highest altitudes, one can obtain the total number of ions produced in the atmosphere by the cosmic-rays; and the result is valid in spite of the existence of a maximum for the measured intensity. From the ionization we can obtain the total energy dissipated by the cosmic-rays, and so if we know the average energy of the rays at entry into the atmosphere, we can determine their number. The blocking effect of the earth's magnetic field presents a lower limit to the energy at any particular place; and while the lower limit in question varies with the nature of the particle, being different for electrons from what it is for protons, for example, the difference for the energies concerned is not of great importance in calculations of this nature. Knowing, therefore, the lower limit of energy at any one place, we can find the average energy if we know the law of distribution of energies. The latitude effect at sea-level, in so far as it is determined by the earth's magnetic field and by the distribution of energies in the in-coming rays, serves as a means of determining that distribution over the ranges of energy lying between the entrance energy for the equator and the entrance energy at any other place where a determination of the intensity has been made. This fact has been pointed out by T. H. Johnson [26] and by H. Zanstra [27] independently. For energies above the minimum energy of entry at the equator one must assume some form of law of distribution of energy among the rays and determine the constants associated with it. Dr. Johnson assumes a law of the form

[25] T. H. Johnson, *Phys. Rev.*, **53**, 499 (1938).
[26] T. H. Johnson, *Phys. Rev.*, **45**, 569 (1934).
[27] H. Zanstra, *Naturwiss.*, **22**, 171 (1934).

$F(E) = A/E^p$, where $F(E)$ is the coefficient of dE in the expression for the number of entering rays (from all directions) lying between the limits E and $E + dE$, and p is a constant to be determined to fit the latitude effect. The value of p assumed by Dr. Johnson is $p = 3$.[28] With the form of $F(E)$ cited and with $p = 3$, the average energy of the entering rays is given by $\bar{E}$, where

$$\bar{E}\int_{E_0}^{\infty}\frac{A}{E^p}dE = \int_{E_0}^{\infty}\frac{AE}{E^p}dE,$$

$$\bar{E} = \frac{p-1}{p-2}E_0 = 2E_0,$$

where E_0 is the lower energy limit for entry determined by the earth's magnetic field. Assigning the appropriate lower limit of energy at any one place, one can obtain the average in question and by dividing it into the total energy passing through unit horizontal area as aforesaid, one can obtain the total number of rays entering the atmosphere through that area. This can be done for all points on the earth's surface, so that the total number of primary cosmic-rays entering the earth's atmosphere can be calculated. Expressed as a current with the assignment of the electronic charge to each individual ray, the total current comes out as 0.13 ampere; and the total power associated with all of the entering rays is one million kilowatts. This seems high at first glance; but the horse-power of the entering sunlight is more than a hundred million times greater.

Relation Between Theories of Cosmic-Ray Phenomena.—As already stated, some years ago I put forth a view as to the origin of the soft component of the cosmic radiation to the

[28] The form $F(E) = A/E^p$ has more fundamentality than that of a purely empirical expression. In its more generalized form $F(E) = A/(E + a)^p$, which avoids an infinite value for low values of E, it has been shown by B. Gross, and independently by myself, to be the form necessary for the production of an exponential law of absorption for primary rays when taken in conjunction with a law of energy loss which I determined (*Phys. Rev.*, **46**, 828 (1934); *Phys. Rev.*, **50**, 1103 (1936) as the law necessary to give an exponential law of absorption for the soft component secondaries. The value of p determined by the writer is $p = 2.5$. A similar form of law has been invoked in the quantum theory already referred to, and here the value of p determined is $p = 2.3$. It thus appears that various independent lines of approach are in harmony with the assignment of a value of p between 2 and 3.

effect that the primary rays entering our atmosphere produce secondaries along their path; and the vital feature of the theory was the assumption that the rate of loss of energy from this cause is proportional to the energy of the primary. The assumption gave rise to an exponential law for the intensity as measured for the secondaries and, since the theory was first suggested, it has gone through various modifications in detail which have been cited in my Director's Reports and elsewhere for the last few years.[29]

The theory in question was designed to leave a good deal of latitude as to the details of the phenomena and as to the primary radiation, the essential thing being that one conceived of an entity, possibly composite in nature, passing through the atmosphere, this entity losing energy by the production of secondaries, the rate of production of these secondaries being at each place proportional to the energy of the entity.

Now in looking into the form and structure of the recently proposed quantum theory of the origin of the soft component, it turns out to be representable as a particular case of the theory to which I have referred and in which the assumptions were formulated on purely empirical bases. I think it serves a clarifying purpose to bring out the relationship and, therefore, I propose to say a few words concerning it.

When translated into the language of my former theory that whole entity of the quantum theory comprising the primary cosmic-ray and all its progeny constitutes the primary of my former theory or the composite entity which was its representative. Now, while this composite entity of the quantum theory is continually producing progeny, it is continually losing energy in the form of ionization; and the energy lost per centimeter of path by all of the secondaries is approximately the same, so that if for simplicity we confine our attention to vertical rays and suppose that there are n such rays, primaries and secondaries, passing through a horizontal square centimeter per second, the loss of energy per centimeter of path by the entity is $-dE/dx$ where

$$\frac{dE}{dx} = -\beta n \qquad (1)$$

[29] W. F. G. Swann, *Phys. Rev.*, **46**, 828 (1934); *Phys. Rev.*, **50**, 1103 (1936).

and where β is the loss in ionization per centimeter of path of a single ray. Now, $E = n\epsilon$, where ϵ is the average energy of all the rays. Thus we may write (1) as

$$\frac{d(n\epsilon)}{dx} = -\beta n \quad (2) \qquad \text{and} \qquad \frac{dE}{dx} = -\frac{\beta E}{\epsilon}. \quad (3)$$

If ϵ, the average energy of the rays, is independent of the altitude, a conclusion which, in fact, is reached in the particular form of solution of the quantum theory which has been investigated, equations (2) and (3) become

$$\frac{dn}{dx} = -\frac{\beta}{\epsilon} n \quad (4) \qquad \text{and} \qquad \frac{dE}{dx} = -\frac{\beta}{\epsilon} E, \quad (5)$$

where ϵ is independent of x. These expressions are of the form of my earlier theory. The progeny, of course, outweigh the primaries in number in any case.

With $\beta = 10^8$ per meter of water equivalent atmosphere, the value of ϵ necessary to give experimental absorption coefficient 0.5 for the soft component is $\epsilon = \beta/0.5 = 2 \times 10^8$ e.v. This value is quite reasonable, and corresponds, in fact, to the average energy of the rays as obtained from cloud chamber data. We are, of course, concerned in all cases only with rays of energy sufficiently great to penetrate our measuring counters.

MISCELLANEOUS THEORETICAL INVESTIGATIONS.

I may make brief reference to two or three theoretical investigations which are too involved to describe here in detail.

The Variation of the Cosmic Radiation During Magnetic Storms.—It is well known that, particularly during periods of sun-spot activity, very appreciable variations in the earth's magnetic field occur. For some purposes these variations can be regarded as the equivalent of an alteration of the strength of that magnet which represents the earth (an alteration of the moment of the earth's dipole) as a result of the causes responsible for the storm.

Recent observations have shown that cosmic-ray intensity varies from its normal value during storms, a fact to which I

have already referred; and it becomes of interest to calculate to what extent such variations can be regarded as results of alterations in the numbers of rays excluded from the earth as the result of the apparent alterations in the earth's magnetic moment. Dr. T. H. Johnson has made such a calculation,[30] and has concluded that the change in magnetic moment necessary to produce the observed variations of cosmic-ray intensity during the storm of April 1937 is of the order 150 times greater than any value simply reconcilable with the magnetic disturbances recorded. It thus seems that we must look elsewhere than in the apparent changes in the earth's magnetism for such cosmic-ray variations as accompany magnetic storms.

The Effect of Galactic Rotation Upon the Intensity of Cosmic Radiation.—The fact that cosmic-ray measurements have suggested variations in the intensity from different directions in space has led to the conclusion that the earth's galactic rotation plays a part, and that it is responsible for such variations of intensity. An intuitive picture illustrating the principle involved is one in which we think of raindrops traveling in all directions and a person running in the rain. He receives more drops per second on his face than on the back of his head.

The calculation of these matters for the case of charged particle cosmic-rays becomes complicated by the disturbing effect of the earth's magnetic field. Finding it necessary to give some consideration to this matter, I succeeded in developing a theory according to which the calculations may be made in relatively simple form.[31] The theory, conforming as it does to the theory of relativity, brings out further certain rather interesting aspects of the details of the phenomenon, aspects which modify very considerably the simple picture of the type founded upon such analogies as those of the raindrops to which I have referred.

The Electrodynamic Force Equation in its Bearing Upon the Evidence for the Existence of a New Cosmic-Ray Particle.—Students of cosmic-rays have recently arrived at the conclusion that, intermediate between the ordinary electron,

[30] T. H. Johnson, *Terr. Mag. and Atmos. Elec.*, **43**, 1 (1938).
[31] W. F. G. Swann, *Phys. Rev.*, **51**, 718 (1937).

which was formerly regarded as the lightest particle in existence, and the proton, which was regarded as the next lightest particle, there exists another particle of intermediate mass. This conclusion was reached by Dr. J. C. Street and Dr. E. C. Stevenson [32] both of whom were formerly Fellows of the Bartol Foundation, and from other considerations by S. H. Neddermeyer and C. D. Anderson.[33]

In questions such as become here involved, questions having so fundamental a relation to the basic bricks of atomic structure, it seems of importance to examine with care the elements which enter into the theory of the determination of the mass. Nearly all quantities in atomic physics are the results of indirect measurements. We do not put an electron on a balance and weigh it. We perform certain experiments whose results we believe to be controlled by the mass sought in a manner which is assumed known; and the mass is calculated as the quantity necessary to provide for the results of our measurements in terms of the theory of the phenomenon concerned. I have been able to show [34] that the mathematical equations which represent the theory of the subject are susceptible of a modification which, while not conflicting with any of their former well-tested duties in science, nevertheless permit a retention of the old value of the electronic mass for the particles which, in the light of the foregoing consideration, and on the basis of the older theories, demanded a special mass.

The Significance of Atomic Entities in Modern Atomic Structure.—In connection with a symposium upon "Philosophical Concepts in Modern Physics" held by the Franklin Institute, I have had occasion to put together and correlate various matters concerned with the fundamentals of atomic structure. The details, being of a philosophical nature, are not adaptable to presentation in brief form, but have been published under the title at the beginning of this paragraph.[35] It will suffice to say that the paper comprises in large measure a discussion of the relations between our pictures of atomic

[32] Abstract No. 40, Meeting of Amer. Phys. Soc., Apr. 29, 1937.
[33] S. H. Neddermeyer and C. D. Anderson, *Phys. Rev.*, **51**, 884 (1937).
[34] W. F. G. Swann, *Phys. Rev.*, **52**, 387 (1937).
[35] W. F. G. Swann, JOUR. FRANK. INST., **225**, 289 (1938).

phenomena and the actual measurements, the significance of reality in relation to these measurements, and the extent to which some of the elements which seem fundamental to the whole structure are, in actuality, irrelevant and figments of the imagination.

INVESTIGATIONS IN MISCELLANEOUS ASPECTS OF NUCLEAR PHYSICS.

Conservation of Energy in the Disintegration of Li^6.—In my former reports I have described the investigations of Dr. L. H. Rumbaugh in designing and developing to operational form an apparatus for separating the isotopes of light elements in weighable and usable amounts. It will be recalled that having separated the isotopes of lithium, Dr. Rumbaugh, in collaboration with Dr. L. R. Hafstad of the Carnegie Institution of Washington, proceeded to bombard the isotopes with high energy particles and establish certain facts concerning the disintegration of these isotopes. Among the phenomena observed was the creation of radioactivity as the result of bombarding Li^7, the radioactive isotope in fact being Li^8.

Dr. Rumbaugh, in conjunction with Drs. R. B. Roberts and L. R. Hafstad,[36] has continued the investigation in the direction of examining the nature of the radioactive disintegration of Li^8. As a result of a number of facts concerned with the radiations accompanying the disintegration, they have come to the conclusion that the Li^8 breaks up according to the following scheme:

One atom of Li^8 breaks up into two alpha particles, a beta particle and a neutrino. The significant part of the conclusion concerns the neutrino which, in the light of all considerations involving the energy of the particles, etc., has to be invoked in order to preserve constancy of energy and momentum in the disintegration.

THE CYCLOTRON.

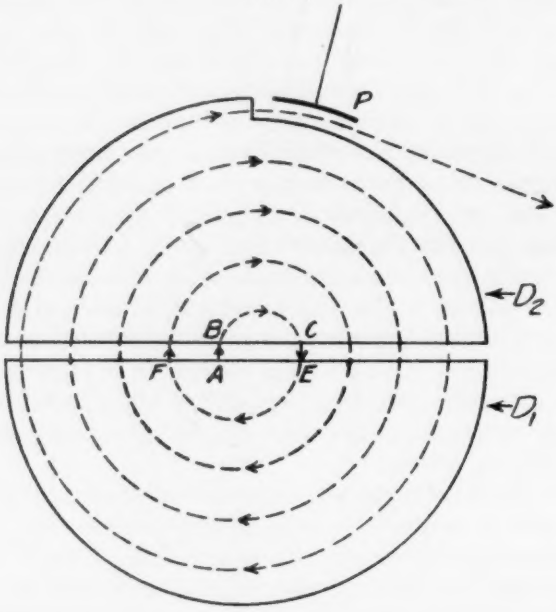
Last year I described the general operation of the cyclotron which was then in process of installation in the Bartol Foundation. This cyclotron, which is the property of the Biochemical Foundation, will be used for biochemical investiga-

[36] L. H. Rumbaugh, R. B. Roberts and L. R. Hafstad, *Phys. Rev.*, **51**, 1106 (1937).

tions by that Foundation and for investigations in pure physics by the Bartol Foundation, which also has the responsibility of its general administration.

Dr. A. J. Allen of the Biochemical Foundation has spent a large portion of the preceding year in supervising the erection of the cyclotron and in getting it into operation. Dr. M. B. Sampson of the Biochemical Foundation has participated in this work and for the last five months Dr. W. E. Danforth, of our laboratory, has devoted the whole of his time to it.

FIG. 27.



For the purposes of explanation, it will be well to repeat here a short section of my report of last year describing the general idea which is as follows:

D_1 and D_2, Fig. 27, are two semicircular portions forming a hollow pancake. A charged particle produced in a manner which I need not describe may be considered as starting at A. A relatively small potential difference of 50,000 volts kicks it across to B. Now the D's are between the poles of a magnet, whose field may be regarded as perpendicular to the paper.

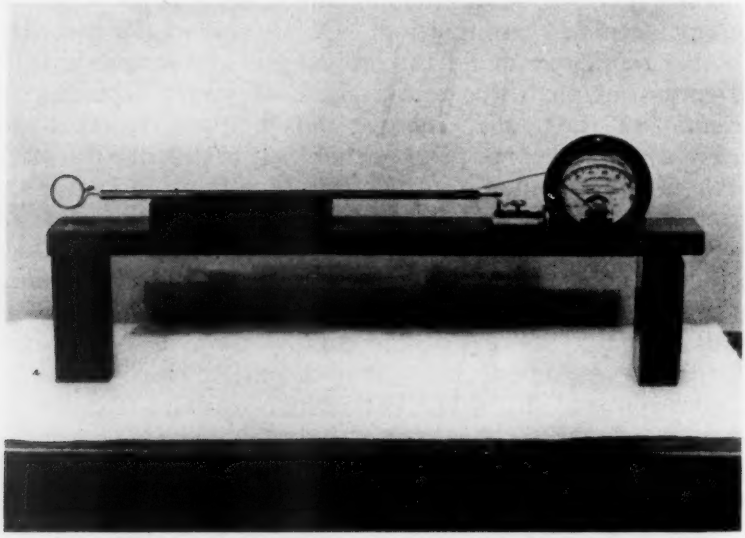
Under these conditions it is well known that the moving particle at B describes a semicircle and comes to C. If the 50,000 volts had remained fixed, the particle would now proceed to cross the gap to D_1 at E. It would be opposed by the electric field and would lose all the energy it had gained in its first kick. However, the 50,000 volts is not constant; it is arranged to be of an oscillatory nature of such period that, by the time the particle has traveled from B to C, the field has reversed, so that, in crossing to D_1 at E the particle's energy is still further increased. On arriving at E it describes another semicircle under the influence of the magnetic field. It turns out that this semicircle is of larger diameter on account of the higher energy; but it turns out that the increase of speed of the particle enables it to describe the semicircle of larger diameter in the same time that it took for the first semicircle, so that it arrives at F just in time for the electric field, which is again reversed, to give it a further kick across to D_2. The particle goes round and round spiralling outwards in this manner, acquiring more and more energy until it finally emerges at the edge of the D's. A charged plate P serves to perform the final deviation which brings the particle outside the D's. The energy which it acquires is, of course, equal to the energy acquired in a single crossing of the D's, multiplied by two for the return journey and multiplied by the number of spirals described.

The main features which have been incorporated since last year are: A new type of oscillator designed to give higher voltage, a new and more accurately made pair of D's, certain structural improvements in the insulating supports, and a water tank to shield the observers from neutrons.

Last February the cyclotron was brought into successful operation for the first time, producing high energy particles of energy six million electron volts for deuterons and a beam carrying a current of one microampere, which was sufficient to produce induced radioactive material in serviceable amounts. Since that time the conditions have been improved to the extent of realizing energies of over nine million electron volts for deuterons; and, while the observed current at this energy is at present only of the order of four microamperes, it is only a matter of further adjustment of detail to realize currents of much larger value.

The incorporation of such a device as the cyclotron brings with it a call for developments of many subsidiary appliances in connection with its operation and with the operation of other things connected with it. In these connections, several members of the Bartol Foundation have participated in various ways.

FIG. 28.

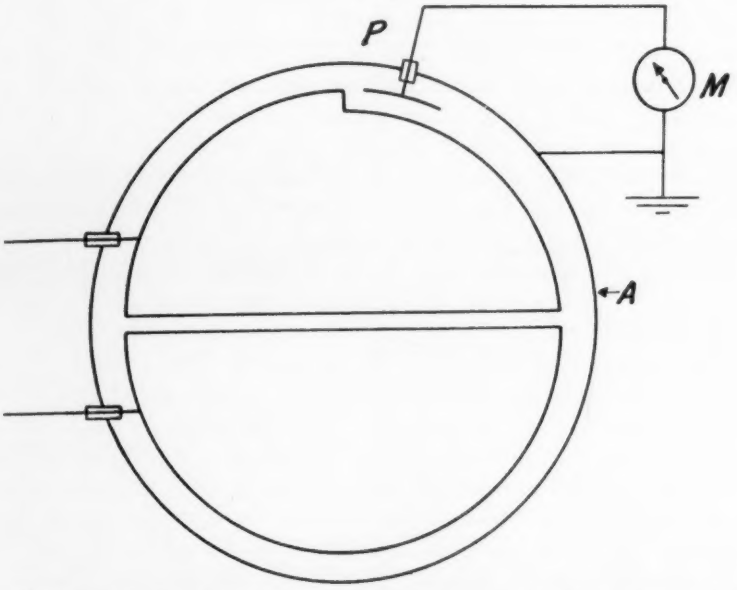


The changing magnetic flux produces an alternating electromotive force in the small coil to the left of the figure. One of the leads to this coil is a metal tube, and the other is a wire within, concentric with, and insulated from the tube. Thus, this part of the circuit contributes nothing to the electromotive force. The thermoammeter to the right of the high non-inductive high-frequency resistance adjacent to it completes the outfit. The unavoidable areas involved in the ammeter region are negligible in their contribution to the electromotive force, on account of the fact that their distance from the current stream to be measured is so much greater than for the coil. Thus, the electromotive force is accurately calculable in terms of the dimensions of the coil and of the alternating flux through it. The high-frequency non-inductive resistance dominates all resistances of the circuit, so that the magnitude of the alternating magnetic field is obtainable from the readings of the ammeter with knowledge of this resistance and of the dimensions of the coil.

Measurement of the Voltage Between the D's.—It is a curious fact that in spite of the importance of realizing a suitably high voltage between the *D*'s to secure proper operation of the cyclotron there seems formerly to have been very little effort in the direction of measuring the actual voltage obtained. The procedure for measuring such voltages under conditions of high frequency is not as straightforward as might at first

sight appear. However, the importance of realizing a satisfactory measurement of voltage led me to design a method adaptable to a portable form of apparatus for such measurement and founded upon measurement of the root mean square value of the current to the *D*'s, this root mean square value being obtained by measuring the line integral of the magnetic field around the conductors carrying the current.

FIG. 29.



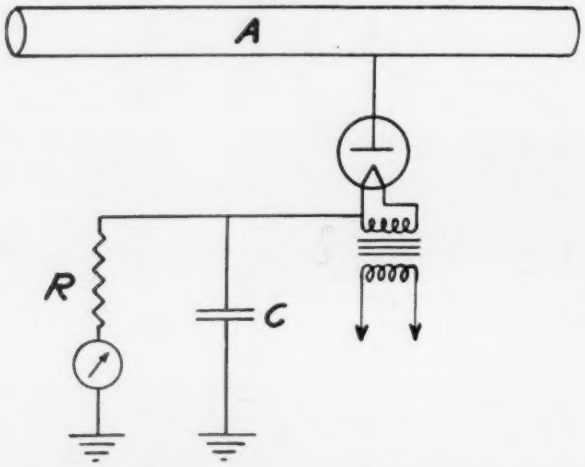
The diagram is self-explanatory and it will suffice to say that the maximum voltage of the *D* is related to the current reading of the thermoammeter by an expression which involves the coefficient of capacity of the deflection plate and the coefficient of induction between it and the adjacent *D*. The resistance between the deflector plate and ground is also involved to an extent which is usually negligible.

The device has the advantage that one can measure the variation of the current along the conductors leading to the *D*'s and so ascertain the characteristics of the oscillatory circuit which it may be of advantage to know. This device was put into successful operation [37] by Dr. W. E. Danforth and is shown in Fig. 28. Dr. Danforth and Dr. Sampson also devised another scheme [37] founded upon measurement of the

[37] W. E. Danforth and M. B. Sampson, *R. S. I.*, **9**, 1 (1938).

induced current through a lead connecting the electrode P, Fig. 29, to ground. They further adapted to this purpose a method [37] whose principle is quite well known and founded upon connecting one of the D's through a rectifier to one plate of a condenser, whose other plate is connected to ground, and measuring the voltage built up in the condenser by measuring the very small leakage current from it through a high resistance to ground. Schematic representations of

FIG. 30.



If the resistance R were infinite, the alternating potential of A would, by action of the rectifier, build up the insulated plate of the condenser C to the peak voltage of A. If R is high, the potential actually built up is approximately equal to the aforesaid peak voltage; and in any case differs from it by a calculable amount. The ammeter shown measures the current, whose product into the resistance R gives the peak voltage desired.

these methods are given in Figs. 29 and 30, in which the legends describe the details.

Measurements of Neutrons.—A cyclotron, when in operation, gives rise to neutrons through various different kinds of atomic processes. The neutrons are neutral particles and they possess very curious characteristics. They pass very readily through lead but are stopped very efficiently by suitable thicknesses of paraffin, water, and other substances containing hydrogen. The reason is that a neutron on encountering a hydrogen atom finds it easy to knock out the proton, which is the positively charged nucleus of that atom, and in this act the neutron loses some of its energy.

It is not as easy to detect and measure neutrons as it is to detect and measure charged particles, since the latter produce ions in passage through a gas and the former do not. One has to rely for the measurement of neutrons upon detection of other things to which the neutrons give rise and which are susceptible of detection. In particular, if one passes neutrons through hydrogen of sufficiently high pressure to insure that the protons produced in the hydrogen by the neutrons describe the whole of their paths in the containing vessel, one can, from a knowledge of the ionization produced, deduce the number of protons produced and this is proportional to the density of the gas and to the number of neutrons which have passed through it. Such a method provides, therefore, a means of measuring the relative intensities of beams of neutrons. It has occurred to Dr. and Mrs. Montgomery to apply this method to the end of devising a reliable means of measuring neutron beams, and, while the experiments incidental to the development are in progress, they give every promise that the method will prove a success.

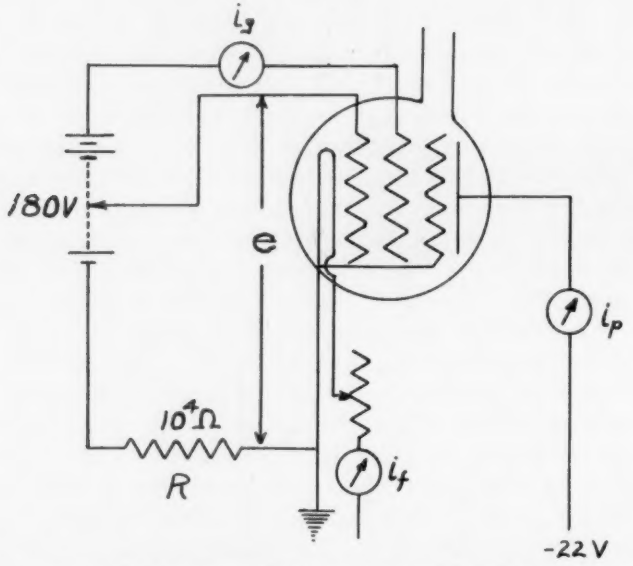
A somewhat analogous method has been devised by Dr. G. L. Locher and involves filling a cloud chamber with hydrogen, firing neutrons through it and counting the tracks of the protons produced in a known interval of time. This method is specially adaptable to low energy neutrons which produce protons of sufficiently short range to enable them to complete the whole of their tracks within the cloud chamber. In order to apply it one has to measure the number of tracks produced in a known time. To this end, Dr. Locher uses a cloud chamber which allows photography of tracks to be made by the light of a spark which lasts for only 10^{-4} or 10^{-5} seconds. Two photographs are taken following the expansion, and the number of tracks appearing in the interval between the photographs, in combination with a knowledge of the interval between the photographs, enables the desired results to be calculated.[38]

Design of a New Vacuum Gauge.—As in many investigations, it becomes necessary, in connection with the cyclotron, to measure high vacua with convenience and rapidity. The

[38] At this stage a demonstration of the operation of a cloud chamber was given, the tracks being projected upon a screen.

device formerly used for this purpose was in its entirety elaborate in design and not very simple in operation. For these reasons, Dr. and Mrs. Montgomery, who, in connection with various devices, have had occasion to investigate the potentialities of sundry forms of vacuum tubes for various purposes, have succeeded in adapting one of them in such a manner as to create a pressure measuring device of extreme simplicity and convenience in use.[39] Figure 31 gives a de-

FIG. 31.



The vacuum tube, which is connected to the chamber whose pressure is to be measured, is a standard type 47. The circuit is self-explanatory. With this arrangement, when the current i_g tends to increase, the potential of the first grid will tend to decrease because of the increased potential drop across the resistance R. This will, in turn, decrease i_g, and the ionization current is thus maintained constant.

scription of the method in the caption. It will suffice here to say that the device is founded upon the well known method of measuring the positive ion current generated in the residual gas of the partial vacuum by a beam of electrons of fixed and known intensity and energy. The normal constancy of the electron current from the filament tends to become vitiated in the use of such a device for measurement of high vacua, because the electron current depends upon the temperature

[39] C. G. Montgomery and D. D. Montgomery, *R. S. I.*, **9**, 58 (1938).

of the filament and its state of activation. These, in turn, depend upon the pressure of the gas and so vary, of course, with the vacuum to be measured. The complexity of the customary devices results from the procedures necessary to keep the electron current constant; and it is in the simplification of this feature that the instrument devised by Dr. and Mrs. Montgomery has its chief merit.

I have one of these instruments on the table. It is measuring the pressure in a vessel by the deflection of a spot of light upon a scale. We will produce a very slight alteration in the vacuum and an immediate alteration of the deflection of the spot will be observed. The actual deflection in the present instance is 10 cms. and this deflection corresponds to a change of pressure of 10^{-5} mm. of mercury, or about 10^{-8} of an atmosphere. It may be interesting to cite the magnitudes involved in another way. A deflection of 1 mm. on the scale corresponds to a change in the amount of gas in the vessel which amounts to only one ten billionth of the amount of gas required to fill it at atmospheric pressure. This small amount of gas, in comparison with the amount to fill the vessel at atmospheric pressure, is like 70 cents in comparison with the seven billion dollars about to be expended to relieve the recession.

Production of Mutations in Fruit Flies by Neutrons.—The relation of atomic radiations, and particularly *X*-radiations, to problems of genetics has become of increasing importance during recent years; and, in particular, evidence has been reported for the production of mutations by such radiations. Dr. G. L. Locher, in collaboration with Miss Mary Nagai, a student of biology at the Rice Institute, has carried out some investigations upon the effect of neutrons in producing mutations.[40] In this investigation, Dr. Locher is indebted to the courtesy of the American Oncologic Hospital and of its director, Dr. G. M. Dorrance, for the use of the 4-gram radium bomb whose gamma rays he used to bombard a beryllium block for the purpose of producing the beam of neutrons with which the flies were irradiated. Subsequent to irradiation, the flies, with their controls, were sent to the Rice Institute where the biological work was done by Miss Nagai.

[40] Mary A. Nagai and G. L. Locher, *Genetics*, 23, 179 (1938).

The results were examined from a statistical standpoint by Dr. F. E. Ulrich of the Rice Institute, and the main conclusions may be summarized as follows:

Fast neutrons are capable of increasing normal mutations. With a beam of neutrons produced by bombarding 500 grams of beryllium from an adjacent 4 grams of radium, and with the flies at a distance of 15 cms. from the center of the beryllium, the normal mutation rate was altered by a factor of 2.6 as the result of a 36 hour bombardment. This factor represents six times the probable error as calculated from statistical considerations. Any effect due to slow neutrons was sufficiently small to be indistinguishable from the statistical fluctuations.

Further Developments in Geiger-Mueller Counters.—The developments of modern nuclear physics and of problems concerned with biophysical investigations have called for an increasing variety of needs and characteristics in Geiger-Mueller counters used for the detection of the radiations involved. In particular, one has need of counters sensitive to different ranges of visible and invisible light. One has need of very thin-walled counters which will permit the entry of rays of very small energy. One has need of counters in which the walls themselves may be subjected to the production of artificial radioactivity in their material, so that through the measurement of such radioactivity one may estimate the strength of beams of neutrons and the like. With all such purposes and many others in view, Dr. Locher has continued his study of Geiger counters and has extended the development of these devices in many directions. In particular, during the last year, he has extended the photoelectric counters to respond down to 8000 A in the infra-red by the introduction of caesium coating on the internal wall of the cylinder of the counter. He has also perfected, with the assistance of Mr. A. G. Nester, some extremely thin-wall counters in which the conducting cylinder is formed by a coat of graphite painted on the inside of a very thin-walled glass tube. The stopping power of the walls of these counters is the equivalent of no more than 15 cms. of air. Dr. Locher has also investigated a number of matters pertaining to the use of different kinds of gases, and different gas pressures in the

counters, as well as phenomena relating to the surface conditions. These matters are too detailed for brief exposition and will be discussed in greater detail in the final publications concerning them.[41]

An address such as it has fallen to my lot to give this evening must of necessity comprise a rather miscellaneous selection of material, in spite of the fact that we do endeavor to retain in our various investigations a certain unity of purpose working towards a common goal. In other words, we endeavor to retain some method in our madness, difficult as it may perhaps seem to find it in my lecture.

It was a happy inspiration when "Investigations in Fundamental Problems of Electricity" was designated as one of the main purposes of the Bartol Research Foundation by its founder, whose family we are happy to see represented by Miss Bartol this evening. The Foundation came into existence when the field of electricity, having in its earlier life sheltered the facts of electrical engineering and applied science, was rapidly expanding its wings over an ever-widening territory which now embraces the most fundamental facts controlling the processes of nature. We, of the Bartol Research Foundation, deem ourselves fortunate in having had the opportunity of adding a few stimuli to these spreading wings.

APPENDIX.

PUBLICATIONS OF THE BARTOL RESEARCH FOUNDATION FROM APRIL 22, 1937 TO APRIL 20, 1938.

Effect of Galactic Rotation Upon the Intensity of Cosmic Radiation—W. F. G. SWANN. *Phys. Rev.*, **51**, No. 9, pp. 718–720, May 1, 1937.

Determination of the Shower Producing Efficiency of Cosmic-Ray Particles—W. E. RAMSEY AND W. E. DANFORTH. *Phys. Rev.*, **51**, No. 12, p. 1105, June 15, 1937.

Conservation of Energy in the Disintegration of Li^8—L. H. RUMBAUGH, R. B. ROBERTS, AND L. R. HAFSTAD. *Phys. Rev.*, **51**, No. 12, pp. 1106–1107, June 15, 1937.

[41] At this point a demonstration was given involving the properties of several types of counters. Very thin-walled counters were shown detecting the very weak energy radiations from potassium and other weak radioactive sources, and a number of ultra-violet counters were shown in operation. As part of the illustration, radioactivity produced by the cyclotron in window glass and other materials was demonstrated.

Production of Mutations by Neutrons—M. NAGAI AND G. L. LOCHER. *Nature*, **140**, p. 111, July 17, 1937.

The Electrodynamic Force Equation in its Bearing upon the Evidence for the Existence of a New Cosmic-Ray Particle—W. F. G. SWANN. *Phys. Rev.*, **51**, No. 5, pp. 387–390, September 1, 1937.

Report on the Work of the Bartol Research Foundation, 1936–37—W. F. G. SWANN. JOUR. FRANK. INST., **224**, No. 4, pp. 415–473, October, 1937.

Cloud Chamber Investigations of some Cosmic-Ray Interactions with Matter—G. L. LOCHER. JOUR. FRANK. INST., **224**, No. 5, pp. 555–582, November, 1937.

The Energy Flux of the Corpuscular Cosmic Radiation—C. G. MONTGOMERY AND D. D. MONTGOMERY. *Phys. Rev.*, **53**, No. 2, pp. 193–195, January 15, 1938.

Artificial Radioactivity Produced by Cosmic-Rays—W. E. RAMSEY, C. G. MONTGOMERY, AND D. D. MONTGOMERY. *Phys. Rev.*, **53**, No. 2, p. 196, January 15, 1938.

A Grid Controlled Ionization Gauge—C. G. MONTGOMERY AND D. D. MONTGOMERY. *Rev. Scient. Inst.*, **9**, No. 2, p. 58, February, 1938.

The Significance of Atomic Entities in Modern Atomic Structure—W. F. G. SWANN. JOUR. FRANK. INST., **225**, No. 3, pp. 289–308, March, 1938.

On the Variations of Cosmic Radiation During Magnetic Storms—T. H. JOHNSON. *Terr. Mag. and Atmos. Elect.*, **43**, No. 1, pp. 1–6, March, 1938.

The Production of Mutations in Drosophila with Neutron Radiation—MARY A. NAGAI AND G. L. LOCHER. *Genetics*, **23**, pp. 179–189, March, 1938.

An Extremely Light High-Potential Battery of Long Life—W. E. RAMSEY. JOUR. FRANK. INST., **225**, No. 4, pp. 401–409, April, 1938.

The Intensity of the Primary Cosmic Radiation and Its Energy Distribution—T. H. JOHNSON. *Phys. Rev.*, **53**, No. 9, pp. 499–501, April 1, 1938.

Science and Human Happiness—W. F. G. SWANN. *Jour. Adult Educ.*, **10**, No. 2, pp. 117–122, April, 1938.

PAPERS PRESENTED AT VARIOUS MEETINGS BUT NOT PUBLISHED

Presented before the American Physical Society.

Denver, Colorado, June 25–26, 1937.

Further Experiments on the Geomagnetic Cosmic-Ray Effects and Their Bearing Upon the Composition and Energy Distribution of the Primary Rays—T. H. JOHNSON.

Radio Balloon Measurements of the Cosmic Radiation in the Stratosphere—T. H. JOHNSON.

Indianapolis Meeting, December 28–30, 1937.

Cosmic Radiation and the Earth's Magnetism—T. H. JOHNSON.

Photoelectric Geiger-Mueller Counters with Caesium Cathodes—G. L. LOCHER.

New York Meeting, February 25–26, 1938.

The Multiplicative Theory of Showers as Applied to the Large Bursts of Cosmic-Ray Ionization—C. G. MONTGOMERY AND D. D. MONTGOMERY.

Washington Meeting, April 28–30, 1938.

Circuits for the Control of Geiger Counters and for Scaling and Recording Their Impulses—T. H. JOHNSON.

Bursts in Cosmic-Ray Ionization in the Equatorial Zone—S. A. KORFF.

Presented at the Philadelphia Meeting of the American Philosophical Society, November 26–27, 1937.

Cosmic-Ray Showers Below Sea-Level—W. F. G. SWANN AND W. E. RAMSEY.

Presented at the Washington Meeting of the American Geophysical Union, April 27–29, 1938.

Correlation of Geomagnetic Cosmic-Ray Effects—T. H. JOHNSON.

Presented before the Chapter of Sigma Xi, of the Carnegie Institute of Technology, April 2, 1938.

What has become of Reality in Modern Physics?—W. F. G. SWANN.

Device Will Determine Carbon Monoxide Content of Air.—(*The Oil and Gas Journal*, Vol. 37, No. 15.) The menace of carbon monoxide has long been recognized in the operation of commercial motor vehicles. Colorless, odorless, and tasteless, carbon monoxide gives no warning. Exposure for one hour to only 15 parts of carbon monoxide to 10,000 parts of air may cause collapse. Breathed in sufficient greater concentration, it causes death. Cases of poisoning are not confined to those who work around motors or other agencies. From a series of tests conducted by the Travelers Insurance Co. and the Cities Service Co., with the joint coöperation of the Motor Vehicle Department and the Department of Health of the State of Connecticut carbon monoxide was found to exist in the interior of private automobiles, generally varying in concentration with the mechanical condition and structure of the car. The new device for ascertaining the content in air is negligible in cost and very simple to construct, materials obtainable from a hardware and drug store. The method employed depends upon the conversion of carbon monoxide into carbon dioxide by combustion and the reaction of this carbon dioxide with an earth-alkali hydroxide, using phenolphthalein as an indicator. The Travelers will follow its usual policy of making the specifications and instructions available to anyone interested in promoting safety and the welfare of those who might be exposed to poisoning. According to J. B. FICKLEN, the inventor, the new detector permits tests to be made at greatly reduced cost. The simplicity of its construction is such that it can be operated by persons having limited knowledge of testing technique.

R. H. O.

GRAPHICAL ANALYSIS OF SURGES IN MECHANICAL SPRINGS.*

BY

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Associate Professor of Engineering Research, The Pennsylvania State College.
Member of The Franklin Institute.

Springs have a wide application in engineering devices. Generally speaking they are subjected to more strenuous conditions of stress and fatigue than other elements of machinery. Their reliability and consistent performance have a vital influence on the performance of the devices of which they form a part.

Usually springs are designed on the assumption that the displacement (compression or expansion) takes place simultaneously in all coils, that therefore the strains and stresses in all points in the spring are equal at any given instant, and that after the motion of the displaced end ceases the spring comes to rest in its entirety. This assumption would involve the motion imparted to one end of the spring being propagated along the length of the spring with infinite velocity. Graphically this condition could be represented by Fig. 1 showing, as a function of time, the displacement of the coils, the velocity of displacement at the moved end of the spring, and the resulting strains (forces, or stresses in another scale) at the two ends of the spring. In Fig. 1*a* the three stereograms illustrate the change of displacement u, of velocity v, and of stress s as a function of time t and location x.

Provided the lift is slow, the spring is short, and the velocity of propagation is high in comparison with the velocity of displacement, then this assumption and representation is substantially correct, i.e., the error incurred is negligible.

Actually, however, the velocity of propagation has a finite value. Originated at one end of the spring the disturbance is propagated along the wire with finite velocity, and only after the lapse of a certain time does it reach the other, stationary

* Manuscript received December 4, 1937.

end; then the stoppage is reflected again toward the moving end where it is set in motion again. This process is represented in Fig. 2 assuming that it takes T_0 time for the disturbance to traverse the length of the spring. As a consequence the change of velocity in the intermediate coils, and also the change of stress, which is inseparably interdependent with the former, are not gradual, but take place abruptly at each reversal of the wave.

FIG. 1.

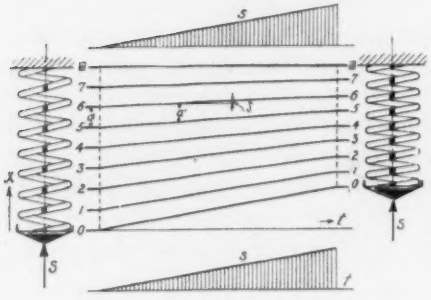
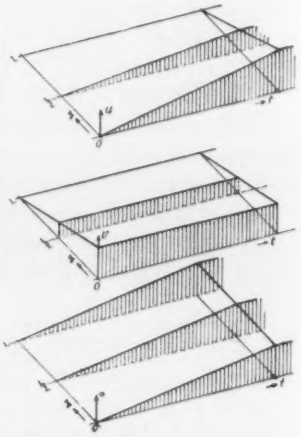


FIG. 1a.



Compression of a helical spring, assuming infinite velocity of propagation. The compression of the eight coils 1, 2, 3 ··· 8 from the uncompressed length (left side) to the compressed length (right side) progresses as a linear function of the time-abscissa. The sloping full lines represent the position of the coils as the function of time. The slope tan δ represents the velocity of a given point in the spring; the proportion of change of length from the original, unstressed state, $\frac{a - a'}{a}$ is proportional to the strain, and to the stress, at that point. The hatched diagrams represent the stress at the two ends of the spring as the function of time.

In Fig. 1a the stereograms of displacement u, of velocity v, and of stress s are shown as the function of time t and location x. After the motion imparted to the movable end of the spring is terminated the spring comes to standstill in its entirety.

The changes of velocity and of stress traveling back and forth along the spring with the velocity of propagation are called surges.

In our previous example we have assumed that the lift duration was an even multiple of the single traversal, T_0. In this case the spring coils come to rest after the completion of the lift, and the final stress is equal to the "static" stress. Generally, however, this is not the case, but there may remain in the spring a residual motion involving stresses exceeding the static value. Assuming, e.g., that the duration of lift is

FIG. 2.

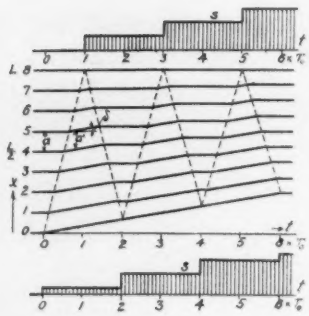
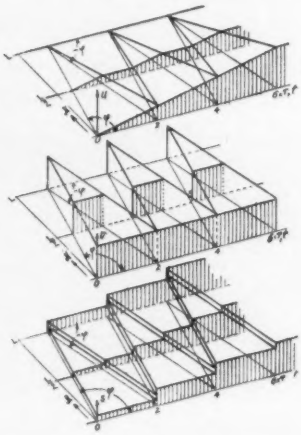


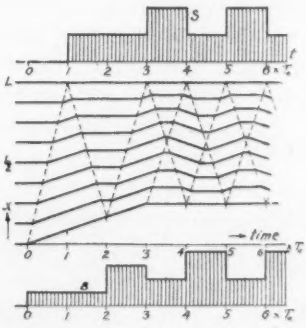
FIG. 2a.



Compression of a helical spring, assuming finite velocity of propagation. The dotted lines represent the location of the disturbance front as it travels from the first coil to the subsequent coils. After the disturbance reached the 8th coil which is resting against a stop the stoppage is communicated to the neighboring coils in the reverse direction. The broken full lines represent the position of the coils as a function of time. In a manner similar to Fig. 1 the slope tan δ represents the velocity of a given point in the spring; the proportional change of length from the original, unstressed state, $\frac{a - a'}{a}$ is proportional to the strain, and to the stress, at that point. The hatched diagrams represent the stress at the two ends of the spring.

In Fig. 2a the stereograms of displacement u, of velocity v, and of stress s are shown as the function of time t and location x. The duration of the motion is assumed to be an even number of intervals T_0; in this case the spring comes to rest in its entirety after the movable end is brought to a standstill.

FIG. 3.



Compression of a helical spring, assuming finite velocity of propagation, the duration of lift being a non-even number of intervals T_0. The dotted lines represent the location of the disturbance front as it is communicated from a coil to the neighboring coil. The broken full lines represent the location of the coils as a function of time. In this case the motion of the intermediate coils continues even after the movable end is brought to a standstill, and the stresses fluctuate between a higher and a lower limiting value as it is shown in the hatched stress-diagrams.

$3T_0$ the displacements, velocities and stresses will be represented in Fig. 3 showing that under these conditions:

(1) while the two ends of the spring remain stationary there remains a residual motion in the intermediate coils;
(2) after the completion of the lift the spring stress is not constant but fluctuates between a value above and a value below the static value.

This fluctuation of displacement and stress persists after the completion of lift until they are damped out by damping and frictional forces.

In our example we have assumed a single lift. In this case the residuary motion would be in a certain time damped out by frictional and damping forces which are always present in actual springs.

In most actual cases a lift is followed by a drop along the descending face of the actuating cam, which drop would produce another residual fluctuation. Depending on the circumstances of the case it can happen that the residual motion due to the lift is canceled out by the residual motion due to the drop; or, that the two residual motions are additive and a greater amplitude of motion and stress cycle results.

Similar considerations apply when the spring is subjected to periodic lifts and drops, as is the general case in valve springs, and injection pump springs, etc. Depending on the conditions of a given case the residuary motion may not occur, may cancel out, may increase and decrease in a periodical fashion, or may, in unfavorable cases, tend to be cumulative and increase to infinity (theoretically, neglecting damping and friction).

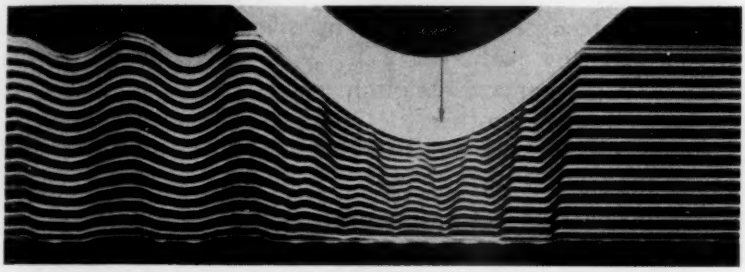
That the surge process as described above is not a theoretical abstraction but corresponds to reality with a close degree of approximation has been amply demonstrated by numerous experiments (see Bibliography). Among these the beautiful photographs of W. Weibull (showing the displacement of the coils) and the oscillograms of W. Marti (showing the end-forces) are outstanding. Some of these experimentally obtained pictures are reproduced in Figs. 4 and 5.

From a design point-of-view the effect of the spring surge is:

(1) that higher spring stresses occur actually than the value calculated under static assumption;

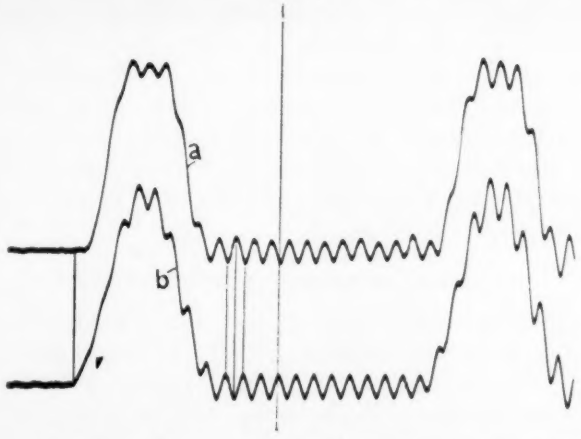
(2) that the spring is subjected to a high-frequency fatigue cycle within a higher-than-static and a lower-than-static stress-range.

FIG. 4.



Photograph of the motion of spring coils by W. Weibull (Royal Swedish Institut of Technology, Stockholm). A weight is dropped on top of an initially stationary spring. The shadow of the coils is photographed on a rotating film drum. Note forward and backward traveling surges.

FIG. 5.



Oscillogram of stresses in a cam-actuated spring (*a* on the stationary end, *b* on the movable end) by W. Marti (Federal Swiss Institute of Technology, Zurich). The spring was located between two quartz-crystal elements, and the resulting stress changes were recorded by an oscillograph. Note that the stress change at the stationary end begins later than at the movable end.

The detrimental effect of the spring surge has been long recognized as an important cause of spring failures, especially in high speed engines (racing-car and aero-engines) in which the springs are numerous and are subjected to exceedingly strenuous service. Numerous methods have been used to mitigate

this effect. One method is to choose the spring characteristics so that no residuary motion occurs, but this condition holds good only for one definite rate and duration of lift and drop, i.e., at one definite frequency of the lift and drop cycle. Another method is to reduce the range between the maximum and minimum surges tresses; this involves the use of short and stiff springs (low value of T_0). Varying the slope of the spring helix (by varying the pitch or varying the coil diameter) has been tried. Another method is to introduce artificial frictional and damping means. There is, however, no panacea against the evils of spring surge. The remedies introduce disadvantageous effects of their own and it is a problem for engineering judgment to strike the happy compromise between the conflicting requirements.

Spring surges formed the subject of numerous theoretical and experimental investigations (see Bibliography). Previous theoretical treatments used preponderantly mathematical methods, which are not apt to convey a full understanding of the phenomena, are laborious to apply, and when used for actual calculation of stresses the results apply only to a given case. The purpose of the present paper is to clarify the theoretical foundation by means of graphical analysis which provides at a glance a complete picture of the phenomenon, is easy to apply and allows the generalization of the results for a wide group of conditions.

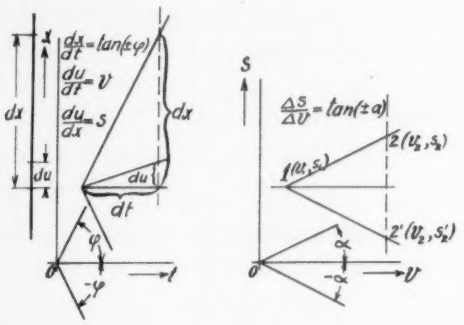
THE GRAPHICAL METHOD OF SURGE ANALYSIS.

Spring surges are a species of the broad family of transient phenomena in elastic columns, which have been exhaustively treated in a previous treatise of the author.[1] While an effort is made to make this paper self-contained and understandable without recourse to other literature, yet for those desirous to acquaint themselves with the broader group of phenomena the study of this reference is recommended.

In Fig. 6 let dx represent a length of spring wire to one end of which a displacement of du is imparted. The disturbance travels along the wire with such a velocity a that after the

[1] Kalman J. DeJuhasz, "Graphical Analysis of Transient Phenomena in Linear Flow," JOUR. FRANK. INST., 223, No. 4, Apr.; No. 5, May; and No. 6, June 1937.

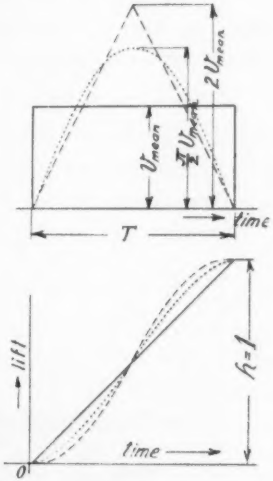
FIG. 6a. FIG. 6b.



Representation of disturbance front in the $t - x$ diagram, illustrating the definition of velocity of propagation, of velocity imparted and of stress.

Representation of distrubance in the $v - s$ diagram, showing interdependence of velocity-change and stress-change. When velocity is changed from v_1 to v_2 then the stress changes either to s_2 or to s_2', situated either on the positive tan α, or negative tan $(-\alpha)$ directrix.

FIG. 7.



Interdependence of velocity-history (Fig. 7*a*) with lift-history (Fig. 7*b*) which are the integral functions of the former. Solid lines denote constant velocity, dash lines the isosceles triangle velocity, and the dotted lines the sinusoidal velocity functions.

lapse of dt time element the other end is reached. In this case the following relationships will hold:

$\frac{dx}{dt} = a$ = velocity of propagation,

$\frac{du}{dt} = v$ = velocity of wire element,

$\frac{du}{dx} = s$ = strain, or, multiplied by suitable factors it may mean stress or force, because the displacement is assumed to take place within the elastic limit.

Thus into the analysis of spring surges four variables enter: the instant of time t, the location in the spring x, the velocity of wire v, and the stress s. The problem can be stated as follows:

Knowing: the design data of the spring, its initial condition of equilibrium and the characteristics of the disturbance as a function of time t,

Determine: the response of the spring as expressed by the velocity v and of stress s at any point x in the spring as a function of time t.

The human mind is incapable of visualizing a four-variable function, therefore in the present treatment the representation is resolved into a pair of tri-dimensional functions, namely:

$$v = f_1(t, x) \qquad \text{and} \qquad s = f_2(t, x),$$

each of which can be represented by a stereogram with the v, resp. s values as ordinates erected over the $t - x$ plane as base. Then the problem resolves itself into finding the data from which this pair of stereograms can be constructed. This is possible with the aid of two interrelationships, namely:

(*a*) the interrelationship between the time and location of the disturbance front which can be represented in the $t - x$ diagram by straight lines having the slope:

$$\frac{\Delta x}{\Delta t} = \tan(\pm \varphi) = \pm a,$$

a being the velocity of propagation along the spring wire.

(*b*) the interrelationship between the velocity-change and the corresponding stress-change which can be represented in the $v - s$ diagram by straight lines with a constant slope:

$$\frac{\Delta s}{\Delta v} = \tan (\pm \alpha) = \text{const.},$$

which in the following will be called "directrices."

The derivation of these relationships is given for various types of springs in the Appendix. The procedure of the graphical analysis is to represent the disturbance in the $t - x$ and $v - s$ charts, obtaining the v and s coördinates for a certain $t - x$ territory, and then proceed to the adjoining territory, as will be illustrated in the examples which follow.

Spring surge problems fall into two main classes:

(1) the spring is not connected to any inert mass; one end of the spring is fixed, the other end is subjected to a motion according to a predetermined history;

(2) one or both ends of the spring are loaded with inert mass, the inert masses being either attached to the spring or only in temporary contact with it (as in a weight dropped on a spring). One end of the spring is subjected to a predetermined motion or predetermined force.

The first class serves as a foundation for the other group of problems; therefore this will be treated in considerable detail.

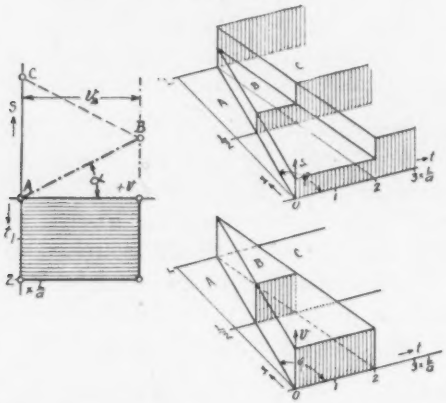
A. Spring Wthout Inert Mass.

Three cases will be considered: (1) the lift-velocity constant, (2) the lift-velocity increases and decreases in a linear fashion, and (3) the lift-velocity is a harmonic function of time. In each case sub-classes are distinguishable according to the duration of lift in terms of single interval T_0.

1. *The lift velocity is constant.* Fig. 8 shows the case when the duration of lift is a double interval: $2T_0$ as shown in the $v - t$ diagram. The initial state of the spring ($v = 0$; $s = 0$) is defined by point A in the $v - p$ chart. This condition holds good in the zone A in the $t - x$ chart. The lift-velocity is represented by the v_B = const. line. The rise of the velocity

from o to v_B is accompanied by the rise of stress to the value of s_B as designated in the $v - s$ diagram by point B found on the intersection of the v_B = const. line with the directrix tan α drawn from the initial point A. Since the other end of the spring is stationary the arriving wave is arrested (v = o) and the corresponding stress increased. The new condition at the stationary end will be defined by the point C found at the intersection of the v = o line (ordinate axis) with the negative directrix tan $(-\alpha)$ drawn from point B. This wave is reflected back again to the movable end, but when it reaches

FIG. 8.



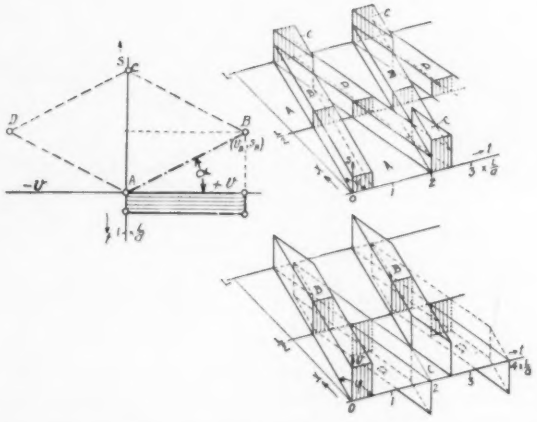
Lift-velocity constant; lift-duration is a double interval = $2T_0$. After the termination of lift-motion the spring comes to rest in its entirety. In the v- and s-stereograms the velocity history and stress-history for the x = o, $x = \frac{L}{2}$ and $x = L$ points in the spring are represented by hatched surfaces. The final stress is equal to the "static" value.

it it is already at standstill (according to our assumption) and no further reflections will take place. From the three points A, B and C in the $v - s$ chart the stereograms of stress and velocity can be constructed. The stress ordinates of the points A, B and C supply the ordinates for the $s = f(t, x)$ stereogram (Fig. 8*b*), and the velocity abscissas of the points A, B and C supply the ordinates for the $v = f(t, x)$ stereogram (Fig. 8*c*). In these stereograms the $s = f(t)$ and $v = f(t)$ values are illustrated (hatched) for the x = o (movable end), $x = L/2$ (middle point) and $x = L$ (stationary end) points in the spring. In each of the zones A, B and C of the stereograms

both the stress values and the velocity values are constant; the changes take place abruptly at the boundaries of the zones. After the completion of the lift the spring comes to standstill in its entirety and no residuary motion remains. Any further lift would start again from a stationary state (no motion) therefore no residual motion will remain if the lift continues till $4T_0$, or $6T_0$ or to any higher even multiple of the $L/a = T_0$ interval.

The case involving a fractional interval of lift-duration is represented in Figs. 9 the duration of lift being in this case

FIG. 9.



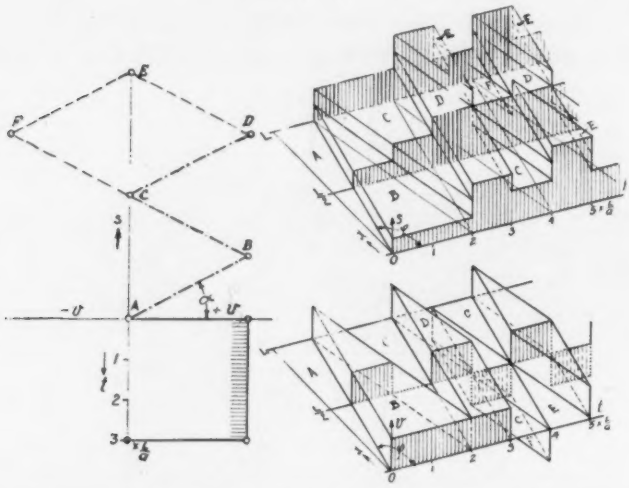
Lift-velocity constant; lift-duration is a fractional interval: $\frac{1}{2}T_0$. After the termination of lift-motion residual surges remain in the spring. Maximum surge-stress corresponds to point C, the minimum to point A in the $v - s$ diagram.

$T_0/2$. The construction is similar to that shown in the previous example. At the termination of the lift the velocity at the movable end is reduced to zero and the state of the spring changes (in the $v - s$ diagram) from point B to point A again. When the surge B reaches the stationary end the velocity is reduced to zero corresponding to the point C, and afterwards to point A. The two series of disturbance lines—the one starting from the $t = 0$ instant and the other from the $t = T_0/2$ instant—divide the $t - x$ field not into triangular zones as in the former case but into triangular and rhomboidal zones as shown in the two stereograms. In the

rhomboidal zone the state of the spring will be D having a negative velocity coordinate. The resulting stereogram of pressure and of velocity are shown in Figs. 9*b* and *c*.

The method of construction is similar for the case in which the duration of lift is $T = 3T_0$ which is represented in Figs. 10 *a*, *b*, *c* for which no further explanation is needed.

FIG. 10.

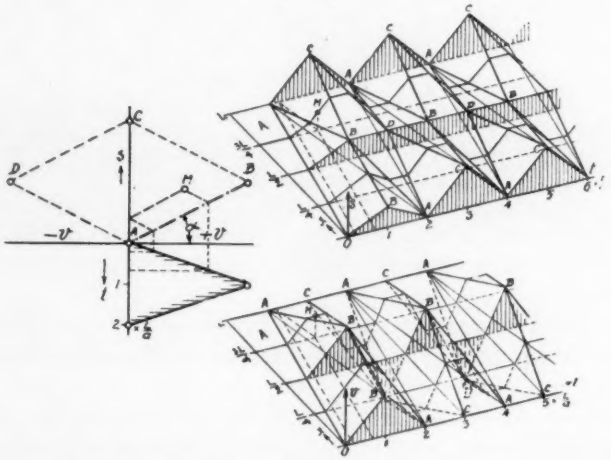


Lift-velocity constant; lift-duration an odd multiple of an interval: $3T_0$. After the termination of lift-motion residual surges remain in the spring. Note, however, that at the $\frac{L}{2}$ point in the spring there is a "node," the stress remaining constant and the velocity fluctuating between positive and negative limiting values. Maximum surge-stress corresponds to point E, the minimum to point C in the $v - s$ diagram.

2. *Lift velocity is a linear function of time.* Fig. 11 shows the case in which the velocity increases from zero to the v_B value and then decreases at the same rate to zero again, the total duration being $2T_0$, as it is shown in the $v - t$ diagram. Owing to the continuous change of lift-velocity during the first two intervals the state of the spring at the movable end will be characterized in the $v - s$ diagram not by the point B but by the line AB. To each point in the zone B in the $t - x$ diagram will correspond a point on the AB line in the $v - s$ diagram. When this wave is reflected at the stationary end of the spring the velocity is reduced to zero and the stress will be defined by the portion CA of the s axis in the $v - s$ diagram.

In the zone C in the $t - x$ diagram both the velocity and the stress will vary from point to point along the spring and also in time from instant to instant. To each point in the zone C as defined by the location x and by the instant of time t corresponds in the $ABCA$ area in the $v - s$ diagram a point defining the pressure and velocity. Within each successive zone the changes of velocity and of stress are defined by slanting planes, each plane joining the neighboring ones in a discontinuous fashion. In this manner the condition of the spring proceeds

FIG. 11.

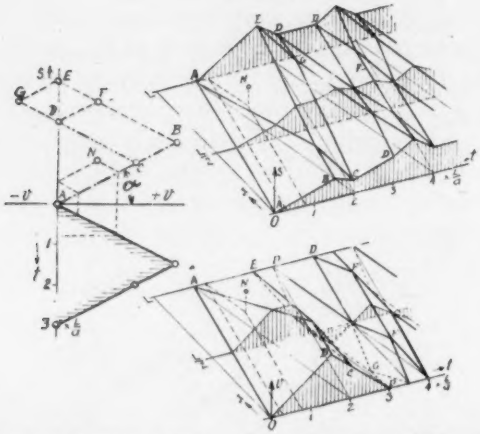


Lift-velocity a linear function of time; lift-duration $= 2T_0$. After the termination of the lift motion residual surges remain in the spring. Note the method of determining the point M in the $v - s$ diagram and its transference into the v and s stereograms. Note that at the $\frac{L}{2}$ point in the spring there is a "node," the stress remaining constant but the velocity fluctuating between positive and negative limiting values. The maximum surge-stress corresponds to point C, the minimum to point A in the $v - s$ diagram.

from state to state as characterized by the points in the $v - s$ diagram. After the termination of lift the spring comes to rest only at its two ends which are themselves at rest. At intermediate points there exists a surge in forward and backward directions, characterized by changing velocities and stresses as it is clearly shown in the stereograms of velocity and stress, Fig. 11*b* and *c*.

The case corresponding to a lift duration of $3T_0$ is represented in Fig. 12*a*, *b*, *c*. The construction is self-explanatory.

FIG. 12.

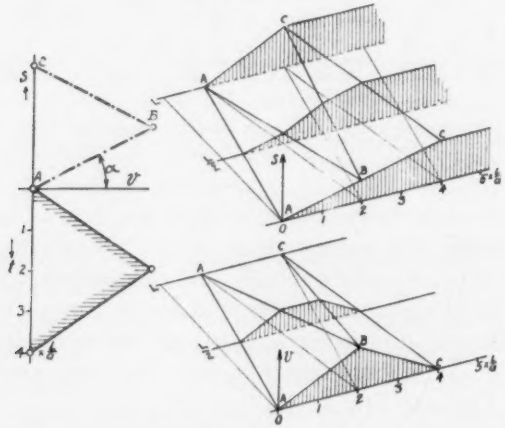


Lift-velocity a linear function of time; lift-duration = $3T_0$. After the termination of the lift motion residual surges remain in the spring. Note the method of determining the point N in the $v - s$ diagram and its transference into the v- and s-stereogram. The maximum surge-stress corresponds to point E, the minimum to point D in the $v - s$ diagram.

Also in this case there remains a residual surge in the spring after the termination of the lift, as it is shown in the two stereograms.

The case corresponding to a lift-duration of $4T_0$ is illustrated in Fig. 13 for which no further explanation is needed.

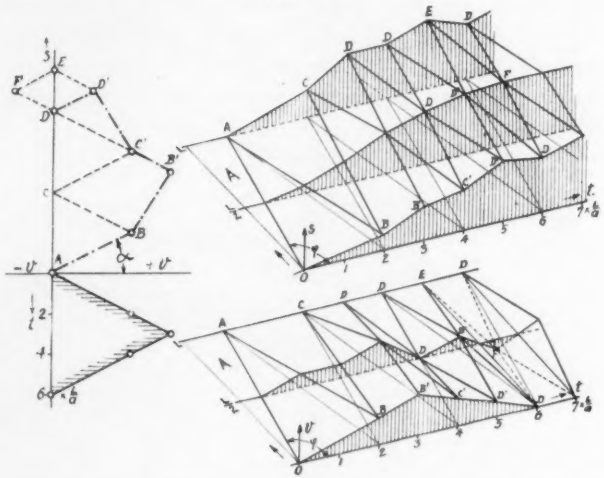
FIG. 13.



Lift-velocity a linear function of time; lift-duration is $4T_0$. After the termination of lift-motion the spring comes to rest in its entirety. The final stress, corresponding to print C in the $v - s$ diagram is equal to the "static" value.

It is seen that in this case no residuary surge remains, but the spring comes to standstill in its entirety after the termination of lift. The lift-duration of $6T_0$ is illustrated in Fig. 14.

FIG. 14.

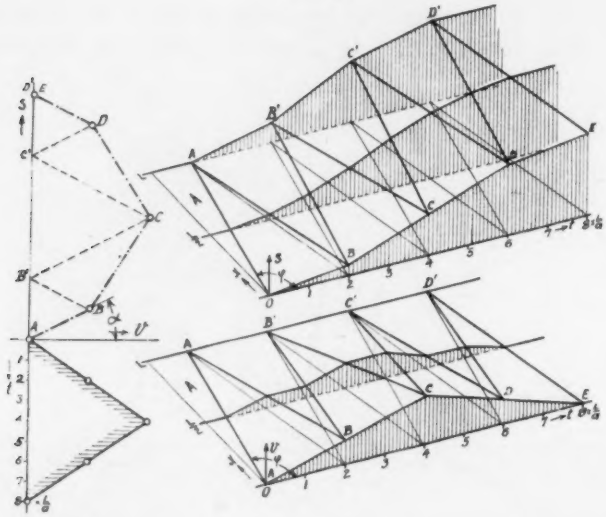


Lift-velocity a linear function of time; lift-duration $= 6T_0$. After the termination of lift-motion residual surge remains in the spring. At the $L/2$ point there is a node, the stress remaining constant but the velocity fluctuating between positive and negative limiting values. The maximum surge-stress is defined by point E, the minimum by point D in the $v - s$ diagram.

It is evident that residual surge will be absent also in cases where the lift-duration is $8T_0$ (Fig. 15) or any higher integral multiple of $4T_0$.

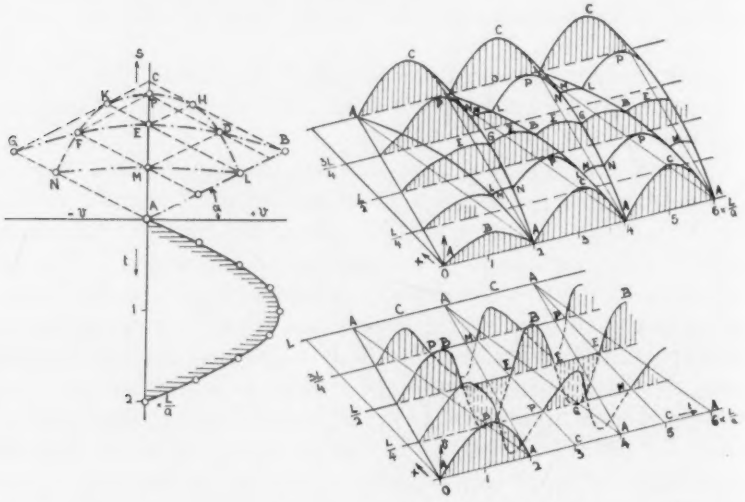
3. *Lift velocity is a sine-function of time.* This case is represented in Fig. 16 for a lift-duration of $T = 2T_0$, and in Fig. 17 for a lift-duration of $3T_0$. As in the former cases, from the $v - t$ diagram the $v - s$ diagram is constructed. The coordinates of the $v - s$ diagram are transferred into the appropriate places in the $t - x$ diagram and thus the stereograms of velocity and of stress are obtained. The procedure is to start from the initial condition of the spring, and find, at the intersection of two directrices the spring condition pertaining to the altered x and t values. It is remarkable to observe that the seemingly intricate stereograms as in Fig. 16 and Fig. 17 can be constructed by simple intersections of corresponding lines. It will be noted that with a lift-velocity obeying the sine-law

FIG. 15.



Lift-velocity a linear function of time; lift-duration = $3T_0$. After the termination of lift-motion the spring comes to rest in its entirety. The final stress, defined by point E in the $v - s$ diagram, is equal to the "static" value.

FIG. 16.



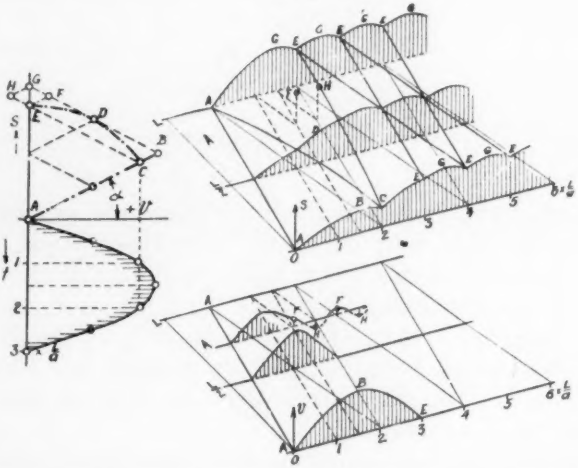
Lift-velocity a sine-function of time; lift-duration = $2T_0$. After the termination of lift-motion residual surges remain in the spring. The maximum surge-stress corresponds to point C, the minimum to point A in the $v - s$ diagram.

there is always some residuary motion remaining in the spring, and it does not come to rest in its entirety after the lift motion has been terminated.

By a similar procedure the $v - s$ diagram and the corresponding stereograms can be constructed for any given law of the lift-motion; but the examples given cover the most important and frequent practical cases.

Maximum and minimum surge-stresses. The foregoing analysis supplied the complete picture of the spring surge,

FIG. 17.



Lift-velocity a sine-function of time; lift-duration = $3T_0$. There remains a small residual surge in the spring but at the $L/2$ point there is a node, the velocity being zero and the stress fluctuating between two limiting values. Note the construction of the points F and H in the $v - p$ diagram and their transference into the v- and s-stereograms. The maximum surge-stress corresponds to point G, the minimum to point E in the $v - s$ diagram.

giving the values of velocity and stress for all points along the spring and at all instants of time. Such a picture is necessary for the full understanding of the phenomenon; but for practical purposes it is sufficient to know the maximum and minimum surge stresses because these values decide the dimensioning, and the fatigue-properties of the spring. From the foregoing examples, after some consideration, it will be evident, that both the maximum and the minimum surge-stresses will occur at the two ends of the spring, while the stress-range at intermediate points will not exceed, and in most cases will be less

than, that at the end-points. Our purpose now will be to determine the maximum and minimum stresses for the three types of lift function (constant, isosceles triangle, and sinusoidal lift-velocity history) as they are influenced by the lift-duration.

For this analysis we shall assume that in all cases the lift is constant, and equal to unity:

$$\int_0^T v\,dt = v_{\text{mean}}\,T = h = 1.$$

This means that the velocity is inversely proportional to the duration, i.e.,

$$\frac{(v_1)_{\text{mean}}}{(v_2)_{\text{mean}}} = \frac{T_2}{T_1} = \frac{\dfrac{T_2}{T_0}}{\dfrac{T_1}{T_0}} = \frac{r_2}{r_1}.$$

Figs. 18, 19 and 20 show the $v - t$ diagrams, and the $v - s$ diagrams derived from them, for the three types of lift-velocity history. In these, for the sake of clarity of representation, the diagram height has been kept constant, and therefore the velocity-scale has been altered proportionally to the lift duration. Furthermore, the stress-scale has been kept proportional to the velocity scale, so as to keep the slope of the directrix, tan α, constant.

Comparing now the three types of lift-velocity curves the mean velocities for one given duration of lift can be expressed:

(*a*) for a constant lift velocity:

$$(v)_{\text{mean}} = (v)_{\max};\ (v)_{\max} = (v)_{\text{mean}};$$

(*b*) for an isosceles-triangle velocity-history:

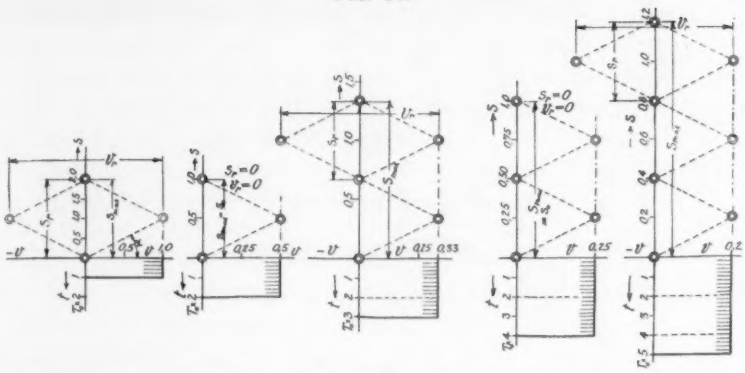
$$(v)_{\text{mean}} = \tfrac{1}{2}(v)_{\max};\ (v)_{\max} = 2(v)_{\text{mean}};$$

(*c*) for a sinusoidal velocity-history:

$$(v)_{\text{mean}} = \frac{2}{\pi}\,(v)_{\max};\ (v)_{\max} = \frac{\pi}{2}\,(v)_{\text{mean}}.$$

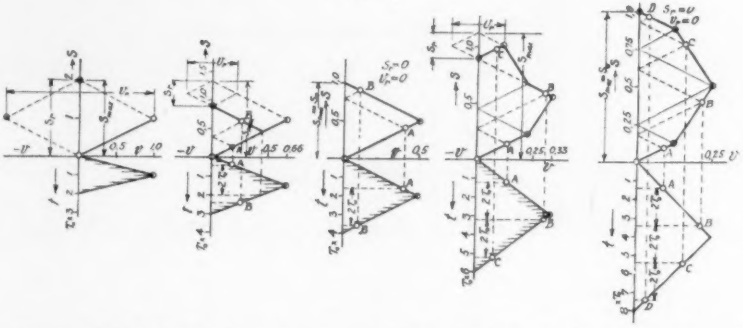
From the data of Figs. 18, 19, and 20 a series of curves can be constructed by purely graphical means showing the max-

FIG. 18.



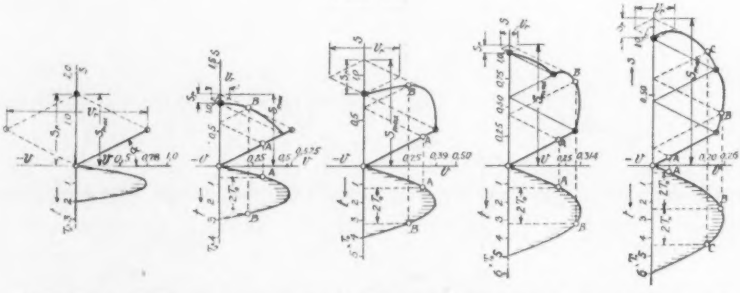
Maximum and minimum stresses, and residual surge velocities for constant velocity of lift. $s_0 = 1$ = static stress; $s_r = s_{max} - s_{min}$; v_r = range of maximum and minimum surge velocities. The conditions are illustrated for lift durations varying from T_0 to $5T_0$. It will be seen that there is no residuary surge for multiples of $2T_0$ lift-duration.

FIG. 19.



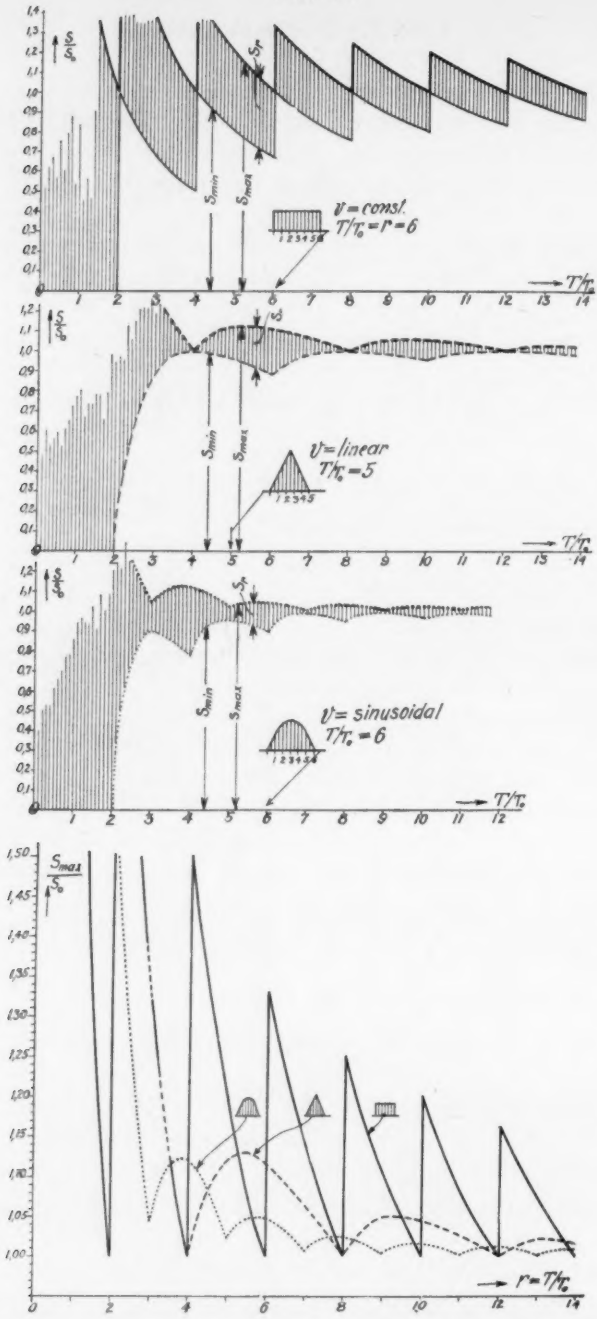
Maximum and minimum stresses, and residual surge velocities; lift-velocity history an isosceles triangle. The conditions are illustrated for lift-durations varying from $2T_0$ to $8T_0$. There is no residuary surge for multiples of $4T_0$ lift-duration.

FIG. 20.



Maximum and minimum stresses, and residual surge velocities; lift-velocity history a sine line. The conditions are illustrated for lift-durations varying from $2T_0$ to $6T_0$. There remains in the spring at every lift-duration a greater or smaller residual surge.

FIG. 21.



Maximum and minimum stresses (static stress being taken as unity) as a function of the lift-duration (the interval T_0 being taken as unity); (*a*) for a constant lift-velocity; (*b*) lift-velocity-history an isosceles triangle; (*c*) lift-velocity-history a sine-function. The hatched territory represents the range between the maximum and minimum stresses. Fig. 21*d* shows the maximum stresses at a larger scale.

imum and minimum stresses as the function of lift-duration, as shown in Figs. 21*a*, *b*, *c*, *d*. Actually, however, for the sake of greater accuracy these curves have been calculated from the formulas given in Table I the derivation of which is based on the following line of thought.

The change of stress due to a change of velocity can be expressed, as stated before, by the equation

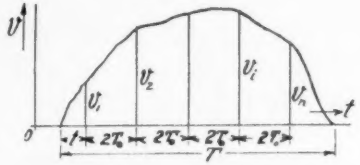
$$\Delta s = \tan \alpha \cdot \Delta v.$$

Assuming now an arbitrary lift-velocity curve, Fig. 22 the stress due to the velocity imparted to the movable end at the instant t will be

$$s_1 = \tan \alpha \cdot v_1.$$

The stationary end is reached after T_0 interval, where the velocity is reduced to zero and the stress is increased to

FIG. 22.



Arbitrary lift-velocity curve. The final stress is proportional to the sum of ordinates $v_1 + v_2 + \cdots + v_i + \cdots + v_n$ taken $2T_0$ intervals apart.

$$s_1' = 2 \tan \alpha \cdot v_1,$$

which is propagated back to the movable end, arrives there after the elapse of a further T_0 interval and the velocity is brought up to v_2; the stress will be

$$s_2 = 2 \tan \alpha \cdot v_1 + \tan \alpha \cdot v_2.$$

On reaching the stationary end the velocity will be reduced again to zero and the accumulated stress will be:

$$s_2' = 2 \tan \alpha \cdot (v_1 + v_2).$$

Thus the stress accumulates at each subsequent reflection of the velocity wave, and after the last velocity wave v_r the total accumulated stress will be:

$$s = 2 \tan \alpha \sum_{i=1}^{n} v_i,$$

i.e., the total surge stress is proportional to the sum of the ordinates of the velocity-diagram, taken $2T_0$ intervals apart.

For a given lift-velocity history and $T/T_0 = r$ value this sum is in some special cases a constant, but in general it is a variable quantity, being a periodic function of the t value corresponding to the first chosen velocity-value v_1, and the period being $2T_0$. For a certain value of t the sum will be maximum: this determines the maximum surge stress. For another t value this sum will be a minimum: this determines the minimum surge stress. These values can be determined for any arbitrary lift-velocity curve by a point-by-point method. If the lift-velocity history is defined by a mathematical expression (as in the above three types of lift-velocity curves) then also the maximum and minimum surge stresses can be expressed by mathematical formulas. The actual derivation is left to the reader; the formulas are given in Table I and the resulting diagrams are shown in Figs. 21*a*, *b*, *c*, *d*.

(*Note.*—Some of these formulas and curves are already contained in the above mentioned treatise of W. Marti (Ref. 15) and agree, save for the different notation, with those given here.)

(*To be continued in next issue.*)

IODINE CONTENT OF OYSTER SHELLS.

BY

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The composition of oyster shells, namely, the high percentage of calcium carbonate and some calcium phosphate along with other elements has made its use universal as poultry food. Hendrick, Lee and Godfrey [1] carried out a number of experiments in which they fed cod liver oil to laying hens, confined without access to direct sunlight. The general condition of the birds was improved, and there was an increase in the thickness, volume and hatchability of the eggs. When no cod liver oil was included in the diet, the addition of oyster shell increased egg production and thickness of the egg shell even though mineral supplement was present in the basal diet. They state that oyster shell thus appears to be a source of easily available mineral or to contain a small amount of some factor which is present in cod liver oil. Coulson [2] investigated the iodine content of fresh oysters, shucked and handled in the usual manner, from all the important producing areas of the United States. The results varied from 1,000 to 11,530 parts per billion on the dry basis, or from 194 to 1,652 parts per billion on the original moist basis. The average for 64 Atlantic and Gulf Coast samples was 492 parts per billion, fresh basis. There was no significant variation in the iodine content of oysters from different localities along the Atlantic and Gulf Coast, however, Pacific Coast oysters were lower in iodine content than the Atlantic Coast samples. Coulson recommends oysters as an excellent source of naturally combined iodine food for the prophylaxis of simple goiter, especially in goitrous regions.

Irrespective of the amount of iodine that has been reported in the living oyster we are not informed as to the possibility of iodine in the oyster shell as it is sold on the market. The shell is a product formed of secretions from the living cells of

the organism. Its chemical composition does not depend entirely upon the environment, but is determined by the hereditary influence on the differentiation of the tissues of an organism. Although the oyster grows in sea water containing iodides, it does not necessarily follow that a relatively large percentage of iodine will be used in the formation of the shell.

The material for analysis was supplied by the Oyster Shell Products Corporation, New Rochelle, N. Y. The shells are dredged from a reef known as Pointe Au Fer Reef, situated in the Gulf of Mexico about six miles off shore from the mouth of the Atchafalaya River, Louisiana, washed thoroughly, pulverized and placed in a direct-fired drier. From here tons of pulverized dried oyster shells are sent out to the open market and sold as poultry food.

The presence of salts interfered with a direct determination of iodine. It was necessary to apply a method whereby the iodine could be separated from these interfering ions. Many preliminary experiments were performed in which the iodide in acid solution was oxidized to free iodine and volatilized with steam, the iodine being received in cooled condensers containing potassium iodide. None of these methods proved to be of sufficient accuracy to warrant their use.

Iodine, if present in oyster shells, may exist as iodides of sodium, potassium, magnesium, calcium or as a complex organic iodine compound.

WATER SOLUBLE IODIDES.

A 50 gram sample of pulverized shell was digested with two 500 ml. portions of hot water. The combined filtrates were made more alkaline with a few drops of potassium carbonate solution and evaporated to dryness. The residue was gently ignited to destroy organic material, dissolved in several ml. of hot water and made acid with sulphuric acid. Sulphurous acid was added to convert any iodate to iodide. The solution was again made alkaline with potassium carbonate, evaporated to a syrupy mass and extracted with 15 ml. portions of ethyl alcohol.* The alcoholic solution was evaporated to dryness, the residue dissolved in a few ml. of water and transferred to a small separatory funnel. To this was

* The alcohol was purified by distilling over lime.

added 1 ml. of carbon tetrachloride * and approximately 1 ml. each of 1 to 1 sulphuric acid and 10 per cent. sodium nitrite. The funnel was shaken vigorously for two minutes. The absence of a pink color in the layer of carbon tetrachloride indicated the absence of water soluble iodides.

The procedure was repeated using a 500 gram sample of the same material. No iodides were present.

The accuracy of the method was checked by leaching, with water, a 50 gram sample to which had been added 0.1 mg. potassium iodide. The final test gave a distinct pink carbon tetrachloride which indicated that very small quantities of water soluble iodides could be detected.

ALCOHOL SOLUBLE IODIDES.

Inorganic iodides of sodium, potassium, magnesium, calcium and possibly organic combined iodides are soluble in alcohol.

A 100 gram sample of pulverized shell was extracted with absolute ethyl alcohol in a Soxhlet extraction apparatus for 18 hours. The alcohol solution was evaporated to dryness. To the residue was added a few ml. of a solution of potassium carbonate. After a second evaporation to dryness, the residue was gently ignited to destroy any organic material. After acidifying with sulphuric acid the same procedure was followed as given under water soluble iodides. This gave a negative test for iodides.

The extraction and test was repeated with another 100 gram sample to which had been added 0.1 mg. of potassium iodide. A distinct positive test for iodides was obtained. This test was not definite for organic combined iodine on account of the possibility of its loss by volatilization with the alcohol.

FUSION METHOD.

A sample was fused with potassium hydroxide in an iron crucible and the melt tested for iodides according to the method of von Fellenberg.[3, 4] Only one analysis was completed, and this gave a negative test for iodides.

* The carbon tetrachloride was purified according to the method given by Snell. "Colorimetric Methods of Analysis," p. 562. D. Van Nostrand Co. (1936).

COMBUSTION METHOD.

The method is similar to that given by McHargue, Young and Ray.[5] They applied the method to the determination of small quantities of iodine in soils from various regions in Kentucky.

20 grams of the pulverized shell were placed in porcelain boats and ignited in a quartz tube for four hour periods at 1050° C. Iodine free air was drawn through the tube during ignition, and the volatile products collected in absorption bottles containing 5 per cent. potassium carbonate solution. Traces of iodine were removed from the air by drawing it through towers containing potassium carbonate solution before entering the furnace. After igniting 100 grams of the sample the potassium carbonate solution was evaporated to dryness and ignited gently to destroy the organic matter. The residue was dissolved in a few ml. of hot water, transferred to a separatory funnel and extracted with three portions of alcohol. After evaporating the alcohol solution, the residue was dissolved in a few ml. of hot water, transferred to a small separatory funnel and tested for iodine.

The following test was used for iodine: The solution was acidified with dilute sulphuric acid, several drops of sulphurous acid were added and the contents shaken. One ml. each of carbon tetrachloride, 18 N sulphuric acid and 10 per cent. sodium nitrite solution were added and the shaking repeated for two minutes. This gave a pink carbon tetrachloride layer. The color was matched with standards prepared in the same way.

The calcined material taken from the porcelain boats was extracted with absolute ethyl alcohol in a Soxhlet extraction apparatus. The alcohol was evaporated and the residue tested for iodides. The calcined material gave a negative test for iodides. This indicated that any alcohol soluble iodides that might have been formed during the heating, decomposed upon ignition, and lost iodine which was recovered in the potassium carbonate solution.

If the iodine was present in the form of organic compounds, the ignition would convert the iodine to iodide. If conversion was incomplete the organic material would volatilize at this temperature. In order to determine if the iodide

(other than organic iodine compound) was all volatilized at 1050° C. the combustion procedure was repeated with a 20 gram sample of pulverized shell to which had been added 0.05 mg. of potassium iodide. The pink carbon tetrachloride layer matched a standard containing the same amount of iodide. (The color obtained from the amount of iodine already present in the shell was considered.) The calcined residue was extracted with absolute ethyl alcohol and gave a negative test for iodine. This definitely proved that all iodine was volatilized by the combustion method.

RESULTS OBTAINED BY THE COMBUSTION METHOD.

Sample 1—Taken from a 100 lb. bag of shell purchased in the open market at Center Hall, Pa. ..... 200 p.p.b.

Sample 2—Taken from a 100 lb. bag of shell purchased in the open market at Erie, Pa. 300 p.p.b.

Sample 3—Taken from a sample of granulated shell before going through the direct fired drier at a plant in Morgan City, Louisiana 500 p.p.b.

The authors wish to thank the Oyster Shell Products Corporation for making this work possible.

SUMMARY.

A report is given of the investigation of the iodine content of oyster shells taken from the reefs found in the Gulf of Mexico. The pulverized shells as sold on the market contain 200 to 300 parts per billion of iodine. Water soluble and alcohol soluble iodides appear to be absent. The granulated undried shells contain 500 parts per billion of iodine. Apparently there is a loss of iodine due to the temperature at which the pulverized shells are dried.

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Research on Prevention of Stream Pollution at Mellon Institute.—In the iron and steel industry an outstanding problem is to prevent stream pollution by waste liquors from such operations as pickling, in which metal is commonly acid-treated. This industry, after endeavoring to solve this problem for many years at heavy expense, has recently founded, through the American Iron and Steel Institute, a fellowship at Mellon Institute of Industrial Research, in Pittsburgh, with the aim of acquiring novel ideas and attempting a definite solution just as soon as possible. According to word from Mellon Institute, this investigation will be carried on thoroughly until concluded to the satisfaction of health and industrial authorities. It will be the objective to treat or process the waste liquor of pickling plants so as to render it entirely safe for discharging into streams, recovering from it chemicals from which useful products can be made economically. Thousands of tons of iron and sulfuric acid are now wasted annually in various districts of this country by the lack of a suitable method of treatment, especially a procedure that can be employed on the large scale necessary in big mills; and through the fellowship at Mellon Institute a concerted effort will be made to take out the chemicals in solution in the liquor by a satisfactory procedure and to discover uses for them. WILLARD W. HODGE, professor of chemical engineering and head of the Department of Chemical Engineering at West Virginia University, and also director of the Engineering Experiment Station of that institution, has been granted a year's leave of absence to head this investigational work at Mellon Institute.

R. H. O.

NOTES FROM THE BARTOL RESEARCH FOUNDATION.

CORRELATION OF COSMIC-RAY GEOMAGNETIC EFFECTS.*

BY

THOMAS H. JOHNSON, Ph.D.,

Assistant Director.

In the theory of the cosmic-ray orbits in the magnetic field of the Earth developed by Störmer and Lemaître and Vallarta the intensity of the cosmic radiation in space outside the atmosphere depends upon five parameters, all of which are subject to independent variation. Corresponding to these there are five geomagnetic cosmic-ray effects, namely, the latitude-effect, the zenith-angle effect at constant azimuth, the azimuthal effect at constant zenith-angle, the radius- or longitude-effect, and the magnetic moment or storm-effect. All of these effects have been reported from observational data and their interpretation given in terms of the theory. In most instances the theory has been used to determine the variation of the low-energy limit of the incident radiation and the energy-spectrum of primary cosmic radiation has appeared in the interpretation as an adjustable parameter. Since all of the effects depend upon this parameter and upon the relative intensities of positives and negatives in the primary beam, we may inquire to what extent the various effects are consistent with one another. Since atmospheric absorption is always present, it will be convenient to refer to the intensity as being proportional to the effects produced after reaching the point of observation by the particular component of primary radiation. Because of the greater wealth of observational data the effects observable in the vertical direction at sea-level will be of principal interest.

In view of Liouville's theorem the intensity, j, of the cosmic radiation on the Earth's surface can be expressed by

* Reprinted from *Transactions*, American Geophysical Union, 1938, Part 1.

sum of two integrals

$$j = \int_{V_c^+}^{\infty} + j_v^+ \, dV + \int_{V_c^-}^{\infty} j_v^- \, dV + K, \tag{1}$$

one of which represents the intensity due to positive primaries and the other that due to negatives. $j_v^{\pm} \, dV$ is the intensity at the point of observation produced by the positive or negative primaries in the energy-range dV, and K is a constant intensity inserted to take account of any possible uncharged radiation, not affected by the magnetic field. The orbital theory defines the low-energy limits $V_c^{\pm}$ of positives and negatives in terms of the magnetic moment M and the radius a of the Earth by a relation which for high energies converges to

$$V_c^{\pm} = 300M(r_c^{\pm})^2/a^2. \tag{2}$$

Here $r_c^{\pm}$ is a purely mathematical function of the latitude λ and direction (specified by zenith-angle and azimuth, ξ and φ, respectively).

From (1) and (2) the five geomagnetic effects in differential form may be expressed as follows.

(I) The latitude-effect—

$$\partial j/j\partial\lambda = -(600M/ja^2)[j_v^+(V_c^+)r_c^+\partial r_c^+/\partial\lambda + j_v^-(V_c^-)r_c^-\partial r_c^-/\partial\lambda]. \tag{3}$$

At all points in the meridian plane, including the zenith, $r_c^+ = r_c^-$, $\partial r_c^+/\partial\lambda = \partial r_c^-/\partial\lambda$ and

$$\partial j/j\partial\lambda = -(600M/ja^2)j_v(V_c)r_c\partial r_c/\partial\lambda \tag{3a}$$

$$j_v \equiv j_v^+ + j_v^-; \quad r_c \equiv r_c^+.$$

(II) The azimuthal effect at constant zenith-angle—

$$\partial j/j\partial\varphi = -(600M/a^2j)[j_v^+(V_c^+)r_c^+\partial r_c^+/\partial\varphi + j_v^-(V_c^-)r_c^-\partial r_c^-/\partial\varphi]. \tag{4}$$

In the zenith

$$\partial j/\partial\varphi = 0. \tag{4a}$$

In the meridian plane

$$\partial r_c^+/\partial\varphi = -\partial r_c^-/\partial\varphi$$

and

$$\partial j/jd\varphi = -(600M/a^2j)[j_v^+(V_c) - j_v^-(V_c)]r_c\partial r_c/\partial\varphi. \tag{4b}$$

(III) The zenith-angle effect at constant azimuth—

$$\partial j/j\partial\xi = -(600M/a^2j)[j_v^+(V_c^+)r_c^+\partial r_c^+/\partial\xi + j_v^-(V_c^-)r_c^-\partial r_c^-/\partial\xi] + (\partial j/j\partial x)(dx/d\xi), \quad (5)$$

where x is the atmospheric-path length. In the east-west plane in the zenith (ξ increasing towards the east) $\partial r_c^+/\partial\xi = -\partial r_c^-/\partial\xi$ and $dx/d\xi = 0$. Hence

$$\partial j/j\partial\xi = -(600M/a^2j)[j_v^+(V_c) - j_v^-(V_c)]r_c\partial r_c/\partial\xi. \quad (5a)$$

In the north-south plane at the zenith (ξ increasing towards the north) $\partial r_c^+/\partial\xi = \partial r_c^-/\partial\xi$ and

$$\partial j/j\partial\xi = -(600M/a^2j)j_v(V_c)r_c\partial r_c/\partial\xi. \quad (5b)$$

(IV) The radius- or longitude-effect—

$$a\partial j/j\partial a = (600M/a^2j)[j_v^+(V_c^+)(r_c^+)^2 + j_v^-(V_c^-)(r_c^-)^2]. \quad (6)$$

In the zenith

$$adj/jda = (600M/a^2j)j_v(V_c)r_c^2. \quad (6a)$$

(V) The magnetic-moment effect—

$$M\partial j/j\partial M = -(300M/a^2j) \times [j_v^+(V_c^+)(r_c^+)^2 + j_v^-(V_c^-)(r_c^-)^2]. \quad (7)$$

In the zenith

$$M\partial j/j\partial M = -300Mj_v(V_c)r_c^2/ja^2. \quad (7a)$$

The simplicity of the equations which refer to the zenith-intensities makes them especially suitable for comparison with the experimental data. Of these (5a) alone contains the difference of the positive and negative intensities while the others contain their sum. If we define $\alpha = j_v/(j_v^+ - j_v^-)$ combination of (5a) with each of the other equations representing zenith-effects gives the following four determinations of α in terms of the experimentally determined geomagnetic effects:

(3a) with (5a)

$$\alpha = (\partial j/j\partial\lambda)(\partial r_c/\partial\xi)_{EW}/(\partial j/j\partial\xi)_{EW}(\partial r_c/\partial\lambda), \quad (8)$$

(5b) with (5a)

$$\alpha = (\partial j/j\partial\xi)_{NS}(\partial r_c/\partial\xi)_{EW}/(\partial j/j\partial\xi)_{EW}(\partial r_c/\partial\xi)_{NS}, \quad (9)$$

(6a) with (5a)

$$\alpha = -(a\partial j/j\partial a)(\partial r_c/\partial \xi)_{EW}/(\partial j/j\partial \xi)_{EW} r_c, \tag{10}$$

(7a) with (5a)

$$\alpha = 2M\partial j/j\partial M(\partial r_c/\partial \xi)_{EW}/r_c(\partial j/j\partial \xi). \tag{11}$$

All of these determinations of α are subject to the accuracy of the measurements of the zenith-angle effect in the east-west plane. This is probably the most accurately measurable geomagnetic effect and the agreement between the values obtained by the four methods may be regarded as a criterion of the consistency of the other observed geomagnetic effects with the theory. This criterion is now independent of the primary energy-spectrum or of the actual distribution between positives and negatives, assuming this to be the same at all energies.

TABLE I.

Results of Computations.

Row	Value and data used	Geomagnetic latitude			
		0°	10°	20°	30°
1	r_c (Lemaître and Vallarta)	0.500	0.490	0.470	0.419
2	$\partial r_c/\partial\lambda$ per degree	0	−0.0015	−0.0035	−0.0075
3	$(\partial r_c/\partial\xi)_{EW}$ per degree	0.0022	0.0021	0.0018	0.0013
4	$(\partial r_c/\partial\xi)_{NS}$ per degree	0	0.0003	0.0007	0.0007
5	$\partial j/j\partial\lambda$ (data of Compton and Turner reduced to vertical intensity)	0	0.0019	0.0028	0.0065
6	$\partial j/j\partial\lambda$ (vertical intensity, data of Johnson and Read)	−0.001	0	0.0037	0.0054
7	$a\partial j/j\partial a$ (Millikan and Neher, Clay, Compton, Hoerlin)	1.3			
8	$M\partial j/j\partial M$ (Forbush, Hess and Demmelmair)	−30			−30
9	$(\partial j/j\partial\xi)_{NS}$ (Johnson, 4300 meters)				0.0008
10	$(\partial j/j\partial\xi)_{EW}$ (Johnson, sea-level)	−0.0017	−0.0015	−0.0013	−0.0009
	(Johnson, 4300 meters)	−0.0026			−0.0022
11	α from latitude-effect	indeterm.	1.78	1.18	1.20
12	α from north–south effect				0.68
13	α from radius-effect	3.4			
14	α from magnetic-storm effect	130			138

Values of the various quantities involved in these equations are tabulated in Table I. The parameter r_c has been computed by Lemaître and Vallarta [1] and its values for the vertical direction are given in the first row. The derivatives of r_c with respect to latitude and zenith-angle listed in the second, third, and fourth rows have also been taken from Lemaître and Vallarta's results and these also apply to the zenith-direction. Experimental values for the latitude-effect, listed in the fifth row, have been scaled from the average curve of

Compton and Turner [2] corrected for external temperature and then reduced to the vertical intensity by the method of Gross. The details of this operation have been described elsewhere.[3] It is extremely difficult to judge the accuracy of the values thus found. The consistency of the original data after the corrections have been applied indicates that the tabulated values can be relied upon to within 20 per cent. The directly measured vertical intensities of Johnson and Read,[4] listed in the sixth row, have been scaled from their average curve and are perhaps somewhat less reliable than the values reduced from the results of Compton and Turner. Since the integrated latitude-effect found by the unidirectional measurements agrees approximately with that found by the analysis by Gross of the results of Compton and Turner, they lend weight to the values listed in the fifth row although the agreement is poor in the individual cases. These discrepancies have been attributed to the local magnetic anomalies in the vicinity of the Panama Canal Zone. In judging the values of the radius-effect listed in the seventh row of Table 1 it must be remembered that the data obtained by any one instrument are meager, and the time elapsed between observations at different latitudes may be long. Since fluctuations of an unexplained character are known to take place at a single station it is obvious that comparisons of intensities measured at different times based upon a few observations may be considerably distorted. The data upon which the figure 1.3 has been based have been compiled by Vallarta.[5] The minimum intensity, according to these data, occurs 90° in longitude west of the point of minimum radius and the amplitude of the longitude-effect is from two to three times greater than can be reconciled with the latitude-effect. It seems probable, however, that the uncertainties of the observational data may be of this order.

The magnetic-moment effect listed in the eighth row has been taken from the observations reported by Forbush[6] and by Hess and Demmelmair [7] during the storm of April, 1937. Other observations [8] on fluctuations correlating with magnetic disturbances suggest that wide variations in the ratio of cosmic-ray to magnetic fluctuations may occur and that during a single storm at different phases of the disturbance

there is no constant ratio of cosmic-ray to magnetic variation. Thus the figure − 30 listed in Table I may be regarded as a very rough estimate of the order of magnitude. In actuality the ratio of the cosmic-ray disturbance to the horizontal-field variation is the quantity determined and this can be converted into the magnetic-moment coefficient only by making assumptions regarding the nature of the magnetic disturbance. Here it has been assumed that the disturbance is due to a circular ring-current near the Earth, and the coefficient calculated according to a method suggested by Chapman.[9]

The north-south effect, listed in the tenth row, was measured at 4300 meters in geomagnetic latitude 29° N. by the writer [10]. The probable errors of the points and the consistency of the determinations at different angles indicate that the value given is correct to within 30 per cent.

The east-west effects, listed in the eleventh row, are probably correct to within ten or 15 per cent. The nature of the asymmetry observations allows one to make a much more accurate estimate of the probable errors than is possible with the measurements of other geomagnetic effects.

Within the allowable errors the values of α listed in rows 11 to 13 are consistent with one another. The magnetic-moment effect, however, leads to a value of α differing from the others in order of magnitude and indicates that this effect is not a true geomagnetic effect of the type considered in the deduction of equation (7).

In interpreting the values listed in Table I it should be noted that $\alpha = 1$ corresponds to 100 per cent. positive intensity; $\alpha = 1.5$ represents a negative intensity equal to one-sixth of the total; the value α less than one listed in line 12 is impossible and must arise from experimental or theoretical errors.

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NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

EYE-PROTECTIVE GLASSES.

Circular C421, which has recently been released, deals with a subject of first importance to everyone—the conservation of eyesight. Eye protection has received much attention from scientists and engineers, because, while the natural protective mechanism of the eye is sufficient to guard against ordinary intensities of illumination, it is inadequate to care for the excessive glare encountered by participants in snow sports, those who take long automobile trips, and men engaged in such industrial occupations as furnace work, gas and electric welding, firing of boilers, etc. For protection against these abnormal light conditions, spectacle glasses of various colors are used.

At intervals during the past 20 years, W. W. Coblentz, chief of the Bureau's radiometry section, has published results of researches on the spectral transmissive properties of various types of colored glasses, designed to protect the eyes from injurious amounts of ultraviolet and infrared radiation. Since reprints of these papers are no longer available, Circular C421 has been issued to supply the continued demand for information on the transmissive properties of different makes of tinted lenses for outdoor wear, and on deeply colored lenses made especially to protect the eyes of industrial workers, including lenses known by the following trade names: Amethyst, Avitint, Azurlite, Bluelite, Calobar, Cerulite, Cruxite, Diantholite, Kalichrome, Noviol, Noviweld, Polaroid, Roselite, Softlite, Solarex, Viopake, etc. For convenience in exposition of the data, the various tinted lenses are grouped under the color that predominates in transmission—amber, green, blue. An introductory section discusses such important incidental question as: Elimination of glare; distortion of colors; confusion of traffic signals; the hazard in wearing colored glasses when driving at night; and the importance of having standard shades, etc.

* Communicated by the Director.

SPECIFICATIONS FOR A PRECISION MAPPING CAMERA.

The requirements of the government agencies interested in crop control, soil conservation, large scale irrigation projects, and the installation of hydro-electric plants have greatly accelerated the photographing of large areas of the United States from the air. It is desirable that these photographs be of such quality and character that they may be satisfactory, not only for present needs, but also for other purposes that may develop, and thus save the expense of reflying territory that has once been photographed. To insure the production of such photographs it is necessary that the airplane camera be of suitable accuracy and correctly calibrated. The American Society of Photogrammetry has recognized this need and has appointed a Committee on Precision Cameras to formulate camera specifications. An article by Irvine C. Gardner, entitled "Specifications for a Precision Mapping Camera," which is published in "Photogrammetric Engineering," presents the results of an investigation made in connection with the work of this committee.

SODIUM NITRATE CRYSTALS.

The work on a method of growing large clear crystals of sodium nitrate described in Technical News Bulletin 252 (April, 1938) has been continued. Several melts have been made recently, varying the details to find which procedure gives the best results. It becomes more and more apparent that purity of the starting material is of the utmost importance. Slow crystallization from the melt appears to be an excellent method of purification; most of the impurities remain in the last third or fourth of the melt, and may be poured off while still melted. It is surprising how much impurity is found to be present, even in reagent-quality material.

ACCELERATED AGING OF LEATHER IN THE OXYGEN BOMB.

For the last two years Joseph Kanagy of the Bureau's leather section has been investigating the behavior of leather in an oxygen bomb, the data to be used in working out an accelerated aging test. Such a test is important in the development of leathers where long service is required as, for example,

bookbinding and upholstery leathers. It would also be a valuable addition to existing test methods and would save time in research.

The results of a previous investigation, referred to in Technical News Bulletin 254 (June, 1938), indicated that when samples of chestnut- or quebracho-tanned leather were dried in an oven at 100° C. for 24 hours and then exposed in the bomb to an atmosphere of oxygen initially at 100 lb./in^2. and aged at 100° C. for 7 days, the results compared favorably with those obtained when similar leathers were aged under normal conditions for 10 years. The present investigation is a continuation of this study. Various tannages of leather and raw hide were exposed in the oxygen bomb under the same conditions as before. The amounts of carbon dioxide and water evolved from some of the leathers and raw hide, when heated in a stream of 100° C., were also determined and these results for the vegetable-tanned leathers were related to their stabilities in the oxygen bomb.

The results, which have been published in full in the August *Journal of Research* (RP1128), indicate that such factors as stability of the tannins to oxidation, tanning properties of the tanning materials, and conditions which weaken the hide substance during the tanning process, are reflected in the results obtained in the bomb. Moreover, the mechanism of the deterioration also appears to be similar to that occurring under normal aging conditions. For these reasons, it is concluded that aging under the accelerated conditions in the oxygen bomb should give valuable indications as to the normal aging properties of a leather.

HEAT OF HYDRATION OF PORTLAND CEMENT.

When water is added to portland cement the processes of hydration and hardening of the resultant paste are accompanied by an evolution of heat. In an investigation by William Lerch, reported in the *Journal of Research* for August (RP1127), the heat of hydration was determined for a number of cements prepared from clinker which had been subjected to various heat treatments to produce different glass contents. The results indicate that, when different cements are ground to about the same degree of fineness, the quantity of heat

evolved at early ages will be dependent on two factors: The oxide composition of the cement, and the glass content of the clinker. The glass content not only influences the heat of hydration directly, but also influences it indirectly, through its effect upon the true compound composition.

SIZES OF WOODEN BOXES.

The promulgation in recent years of a considerable number of simplified practice recommendations for containers suggested to the wooden box industry the desirability of developing a similar program for their product. Accordingly, the manufacturers, acting through the National Wooden Box Association, requested the Bureau to coöperate in establishing a recommendation for sizes of wooden boxes.

Pursuant to the request of the industry, in March 1938, a proposed schedule, formulated by the above-mentioned Association, was submitted for consideration and approval to box manufacturers, canners, food distributors, carriers, and others concerned. A sufficient number of acceptances were received to warrant promulgation of this program as Simplified Practice Recommendation R171-38, Wooden Boxes for Canned Fruits and Vegetables, effective from July 1, 1938.

The recommendation, which comprises a list of inside dimensions for 27 sizes of wooden boxes used in the shipment of canned fruits and vegetables, is based on the schedule of 21 standard sizes of cans covered by Simplified Practice Recommendation R155-37. In addition to the box dimensions, the simplified schedule shows the number of cans to be packed in each box and their arrangement.

A standing committee, composed of members of the industry and allied groups, has been appointed to have charge of the recommendation with a view to keeping it abreast of current practice. The printed issue will list the personnel of this committee and the acceptors of the recommendation, and will include, also, a brief statement of the development of the project.

Until the printed recommendation is available, free mimeographed copies may be obtained from the Division of Simplified Practice, National Bureau of Standards, Washington, D. C.

VEHICLE SCALES: SELECTION, INSTALLATION, AND MAINTENANCE.

Practical advice on the selection, installation, and maintenance of scales for weighing highway vehicles is given on a printed sheet known as "Form NBS 256," which has just been prepared by Ralph W. Smith of the Bureau's Weights and Measures Division.

The difference between "wagon" and "motor-truck" scales is explained, the former being designed for vehicles in which the weight is approximately equally distributed on all four wheels, while the latter can be used when the vehicle has 85 per cent. or more of its weight concentrated over the rear axle.

The importance of selecting a scale of sufficient length is emphasized, since many trucks have a long wheel-base, and some power units and trailers can be uncoupled only with difficulty.

The use of an adequate specification, adherence to which is required in the purchase contract, is recommended as the best insurance that the scale will prove satisfactory.

Even an excellent scale will not give good service unless satisfactorily installed. The importance of a proper site with smooth straight approaches and a deep and well drained pit is pointed out, as well as the necessity of carefully checking the alignment of the scale parts before acceptance. Inspections during installation and a final inspection after the job is finished should be conducted with care. The tolerance recommendations of the National Conference on Weights and Measures, as embodied in the Bureau's Handbook H22, should be followed in the acceptance test of the scale.

Proper maintenance is essential if the scale is to render satisfactory service over a long period. The pit and the parts of the scale should be kept clean. Bearings should be well packed in grease which must not be allowed to become hard. Interference between the scale platform and coping of the pit should be particularly guarded against.

Finally, the form stresses the importance of maintaining a correct zero-load balance, and of not overloading the scale. Periodic inspection by a competent scale mechanic is recommended.

Copies of this form will be sent on request to weights and

measures officials, to bona fide owners of vehicle scales, to purchasers of new scales, and to others interested. Requests should be sent to the Weights and Measures Division, National Bureau of Standards, Washington, D. C.

VEHICLE-SCALE TESTING SERVICE, 1936–1938.

A 39-page mimeographed report of the "Vehicle-Scale Testing Service of the National Bureau of Standards Conducted in Coöperation with the States, November 1936 to May 1938," has just been issued. This is the first of a series of reports on the subject which it is planned to issue annually. Each report will summarize the results in this field from the beginning of the service and will include such analyses, comments, and recommendations as may be considered timely and appropriate.

The report summarizes the results of 967 tests of vehicle scales which were conducted by the Bureau in the following sixteen States: Virginia, North Carolina, South Carolina, Georgia, Florida, Maryland, Delaware, Rhode Island, Maine, New Hampshire, Vermont, New York, Alabama, Mississippi, Louisiana, and Tennessee. It is arranged in five major divisions: (1) statistical data on tests and inspections; (2) newly-installed motor-truck scales; (3) method of test and inspection of vehicle scales developed by the Bureau; (4) requirements for corner tests of vehicle scales; and (5) statement of vehicle-scale tolerances, and related specification paragraphs.

Copies of this Letter Circular LC529 may be had on application to the Weights and Measures Division, National Bureau of Standards, Washington, D. C.

SYMPOSIUM ON NOMENCLATURE OF SUGARS AND THEIR DERIVATIVES.

Even though carbohydrate chemistry has developed to the point where it is now possible to apply a rational system of nomenclature, many ambiguous and unsatisfactory names are in common use. The time is ripe for simplification and, therefore, the carbohydrate chemists of this Bureau, with the cooperation of others in this field, have arranged a symposium on the nomenclature of the sugars and their derivatives to be

held by the Division of Organic Chemistry, Division of Chemical Education, and Division of Sugar Chemistry and Technology, of the American Chemical Society at the Milwaukee Meeting on September 8, 1938. The purpose of the symposium is to bring together the workers in carbohydrate chemistry to discuss and record their views with the ultimate object of obtaining a more systematic and uniform system of nomenclature.

PAPERMAKING STUDIES OF RECORD PAPERS COMPLETED.

The completion of experimental paper making tests in the Bureau's semicommercial paper mill, made to find the effect of papermaking processes and materials on the strength and stability of book papers, marks the end of a series of studies of this kind extending over the past eight years.

The first part of this work dealt with writing papers. Papers were made from different grades of representative commercial rag and wood fibers used for such papers, and were given thorough chemical and physical tests to find the effect of fiber quality; of the beater-sizing materials, alum, rosin, and starch; and of the surface-sizing materials, glue and starch. Similarly, book papers were made from the particular grades of fibers commonly used for their manufacture, but here while rosin-sizing materials only had to be considered, study of the possible effects of the common filling materials, clay, titanium pigments, zinc pigments, and calcium carbonate or chalk, was also included.

This work showed, as have likewise extensive tests of commercial record papers, that the stability of such papers, as found by accelerated aging by heating, is dependent mainly on the celullosic purity of the fibers and the degree of acidity of the papers.

Very stable papers were made from the higher grades of both rag and wood fibers, when the acidity imparted by alum was not excessive. Of the other sizing materials used, rosin had a minor deteriorative effect. No adverse effect on stability was found for starch, and glue surface-sizing improved the stability of the less-stable papers. None of the fillers used for the book papers affected their stability, and that of the less-stable papers was appreciably improved by calcium car-

bonate. A report on the manufacture of the book papers is in the course of preparation. To round out other information obtained, such as effect of sizing and filling materials on strength, it is planned to make printing tests of the book papers and report the results in a subsequent publication.

The information obtained in this work assists the papermaker in his choice of raw materials and in making the best use of them, and adds to the information needed for adequate classification and specification of papers for the various classes of records.

STABILITY OF VISCOSE TYPE OF OZAPHANE PHOTOGRAPHIC FILM.

A new type of photographic film, in some respects particularly adapted for the reproduction and perservation of records, was tested recently by Arnold M. Sookne, research associate of the National Research Council, and Charles G. Weber of the Bureau's paper section. As reported in the *Journal of Research* for September (RP1134), this film consists essentially of a strip of cellophane only 0.002 inch thick. It has no gelatin emulsion, the image being obtained with a light-sensitive dye incorporated within the cellophane base. This new type of film is only one-third as thick as the motion-picture type of safety film now in use for record purposes, and has the added advantages of being grainless, and not readily damaged by scratching.

The material was found to be insufficiently stable for use where the highest degree of permanence is desired. However, it appears to be well suited for uses requiring a life of 25 to 30 years. Longer life is probably not required of the reading-room copies of publications if the original negative copies are properly preserved, so that new positive prints can be made as required.

INDUSTRIAL USES FOR SILVER.

As reported in Technical News Bulletin 254 (June 1938), the American Silver Producers' Research Project to develop new industrial uses for silver, originally organized as a one-year project, was extended for a second year dating from June 1, 1938. Reorganization of the project and its staff to meet the changed conditions has now been completed.

The original Fellowships have all expired, and only those that dealt with research, which on the basis of a survey of the first year's work at each institution seemed most promising, have been extended another year. Research Fellowships were again granted at Lehigh University (Mr. G. R. Van Duzee), Rensselaer Polytechnic Institute (Mr. D. P. Miles), Cornell University (Mr. L. W. Nielsen), and Batelle Memorial Institute (Dr. R. W. Dayton).

Two research associates, Mr. S. V. Wilson and Mr. C. S. Lowe, and a research clerk, Mr. I. H. Bleiberg, have been added to the project staff at the National Bureau of Standards.

Work in the fields which seem most promising is being conducted along the lines briefly indicated below:

Electrical Contacts.—The program, heretofore concentrated on the purely electrical phenomena at the contact, has been widened to include research relating to effect of composition of copper-graphite and of silver-graphite brushes, wear of both brush and ring, harder silver alloys, effect of character of atmosphere, speed and applicability to a.c. operation.

Bearings.—The occasional failure of silver bearings under very light loads, a phenomenon made more striking by the ability of such bearings to stand extreme service conditions, still remains the outstanding problem. However, much progress has been made in coördinating a joint attack by the bearing manufacturers, the engine builders, the military aviation departments and the oil suppliers.

The "oiliness" question is being attacked by making lead, tin and other additions to the silver and by the addition of "oiliness" agents to the oils used. Parts of failed bearings are being examined for some chemical key.

Coatings.—Because silver is eminently suitable for maintaining flavor in stored liquids a major objective of the project is the development of silver-lined containers. There are two main divisions in this field: that of thin coatings, as for cans and various types of containers; and that of thick coatings, as for silver-clad chemical equipment.

The development of a coating that will be free from porosity and possess a minimum thickness so as to insure a large low-cost market is the immediate problem.

In the chemical equipment field it has been shown that

silver-clad steel sheet will withstand all the punishment required to beat it into bowls or other dished shapes and still show good thermal conductivity. The wider adoption of chemical silverware is an objective.

The commercial possibilities of the brush plating method for the coating of various metals with silver are also being explored.

Alloys.—An intensive study is being made at the National Bureau of Standards of certain selected alloy systems that show some promise of exhibiting properties that will offer economic justification of the alloys. In addition, the collection of useful engineering data on many of the 200 alloys prepared by the research associates is being continued as a matter of routine.

The effect of silver additions to tin bronzes has been studied in some detail, as preliminary work had shown appreciable precipitation hardening due to the silver in amounts approximating 5 per cent. Working with cast alloys containing 10 per cent. tin and from 1 to 5 per cent. silver, the 3 per cent. silver alloy was found most interesting and gives high physical properties in the "as cast" condition.

Some interesting effects produced by very small silver additions to ingot iron have been observed. It appears from the limited data now available that the silver additions reduce blow-hole formation and consequently reduce the "rimming" tendency.

Fungicides.—The results of the past year's research in this field were sufficient to justify its continuation. This work indicates that the best possibility from a tonnage standpoint lies in plant sprays and numerous field trials are to be made along this line.

A Progress Report submitted to the sponsors July 1 offers a resume of the work done under each Fellowship during the past year. A limited number of copies of this Sixth Progress Report on the American Silver Producers' Research Project is available upon request. Inquiries should be addressed to A. J. Dornblatt, Senior Research Associate, American Silver Producers' Research Project, National Bureau of Standards, Washington, D. C.

THE FRANKLIN INSTITUTE

LIBRARY NOTES.

The Committee on Library desires to add to the collections of the Institute any technical writings of members who have had occasion to publish such material.

Literary contributions from author-members will be gratefully acknowledged, properly inscribed and noted in the Journal of the Institute.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. Orders received in the morning are filled the same day. The average cost for a print $8\frac{1}{2} \times 11$ inches is thirty-five cents.

The library and reading room are open on Mondays, Tuesdays, Fridays and Saturdays from nine o'clock A.M. until five o'clock P.M., Wednesdays and Thursdays two until ten o'clock P.M. 548 readers made use of the facilities during the twenty-five days of July; 599 visitors consulted the collections during the twenty-seven days of August.

RECENT ADDITIONS.

Agriculture.

ELLIS, CARLETON, AND MILLER W. SWANEY. Soilless Growth of Plants: Use of Nutrient Solutions, Water, Sand, Cinder, etc. 1938.

Astronomy.

LOW, A. M. What New Wonders! The Story of the Pasadena Telescope. No date.

Biography.

Académie des Sciences de l'URRS. Travaux du Congrès Jubilaire Mendeléev. I. 1936.

MACPIKE, EUGENE FAIRFIELD, Editor. Correspondence and Papers of Edmond Halley. 1937.

MACPIKE, EUGENE FAIRFIELD. Hevelius, Flamsteed and Halley. Three Contemporary Astronomers and their Mutual Relations. 1937.

SMITH, DAVID EUGENE. Portraits of Eminent Mathematicians, with Brief Biographical Sketches. 1938.

SULLIVAN, J. W. N. Isaac Newton. 1642–1727. 1938.

Biology and Biochemistry.

ANDERSON, C. G. An Introduction to Bacteriological Chemistry. 1938.

NEEDHAM, JOSEPH, AND DAVID E. GREEN. Perspectives in Biochemistry. Thirty-one Essays Presented to Sir Frederick Gowland Hopkins by Past and Present Members of his Laboratory. 1938.

SMITH, KENNETH M. Plant Viruses. 1935.

Chemistry and Chemical Technology.

GODDARD, F. W., AND E. J. F. JAMES. The Elements of Physical Chemistry. 1938.

IVANOVSKY, LEO. Ausputz-, Färbe-, Glanz- und Schmiermittel für Leder. 1937.

MORGAN, SIR GILBERT T., AND DAVID DOIG PRATT. British Chemical Industry: Its Rise and Development. 1938.

WEBRE, ALFRED L., AND CLARK S. ROBINSON. Evaporation. 1926.

Electricity and Electrical Engineering.

Electrochemical Society. Transactions, 1936–1937, Volumes 69–72. 1936–1938.

O'RAHILLY, ALFRED. Electromagnetics: a Discussion of Fundamentals. 1938.

History.

LANGDON, WILLIAM CHAUNCY. Everyday Things in American Life. 1607–1776. 1938.

Mechanical Engineering.

International Congress for Applied Mechanics. 4. Cambridge. 1934. Proceedings. 1935.

Metallurgy.

International Tin Research Council. Statistical Year Book. 1938.

MCCOMBS, LOIS F., AND MORRIS SCHRERO. Bibliography of Non-Metallic Inclusions in Iron and Steel. 1935.

SIMONS, ERIC N., AND EDWIN GREGORY. The Structure of Steel Simply Explained. 1938.

Physics.

CLARK, C. H. DOUGLAS. A Comprehensive Treatise of Atomic and Molecular Structure. Volume 2, parts 2–3. Two volumes. 1938.

FAIRES, VIRGIL MORING. Applied Mechanics. 1938.

KILBY, CLINTON MAURY. Introduction to College Physics. Second Edition. 1938.

LORENTZ, H. A. Collected Papers. Volume 6. 1938.

MCCORKLE, PAUL. Survey of Physical Science for College Students. 1938.

SUTTON, RICHARD MANLIFFE. Demonstration Experiments in Physics. First Edition. 1938.

WATSON, W. H. On Understanding Physics. 1938.

WESSEL, PAUL. Physik für Studierende an Technischen Hochschulen und Universitäten. Herausgegeben von V. Riederer von Paar. 1938.

Scientific Essays.

HOGBEN, LANCELOT. Science for the Citizen. 1938.

Sugar.

Gilmore's Louisiana Sugar Manual. 27th Annual Edition. 1937–38.

BOOK REVIEWS.

PHYSIK FÜR STUDIERENDE AN TECHNISCHEN HOCHSCHULEN UND UNIVERSITÄTEN, von Ingenieur Dr. Paul Wessel, herausgegeben von Dr. V. Riederer von Paar. 514 pages, illustrations, 13 × 21 cms. Munich, Ernst Reinhardt, 1938.

This book is intended to be used as a text for college grade students, and it attempts to give a clear presentation in as simple a way as possible. The author has taken considerable pains to direct the treatment from the fundamentals to the present position of knowledge of the subject. In doing this, first the broad aspects are considered from the standpoint of its utilization in allied fields such as chemistry and medicine, then the special needs of the physicist are given attention.

The book has three parts, the first two of which are the text proper. In these there is covered in quite some detail mechanics, waves and acoustics, heat, optics, magnetism, electricity, and electrons and atoms, in this order. The discussion is thorough enough to encourage the student towards experiments which confirm what is presented so that knowledge for recitation is impressed. The third part of the book is devoted to short lectures and formulas. This is a rather unusual treatment in that it is a review or survey of the high points or in abstract form, of the main facts which have shown reasonable steadiness through the years. This part of the book contains much of interest as it cleverly avoids sections of topics whose conceptions have changed. Following this there are some 1440 questions for exercise divided into the sections of the book in which the text occurs. On each question the student is referred to the page of the text covering it. A compilation of tables and useful data, and a subject index complete the book. It is profusely illustrated and should appeal to German speaking prospective users.

R. H. OPPERMANN.

SURVEY OF PHYSICAL SCIENCE FOR COLLEGE STUDENTS, by Paul McCorkle. 471 pages, plates, illustrations, 15 × 22 cms. Philadelphia, P. Blakiston's Son and Co., Inc., 1938. Price $2.75.

With the advance of scientific achievement come a great many problems aside from the field of science. One of the foremost of these problems is the adjustment of the social structure to make available the great advances offered as a result of scientific progress. What may be classed as a subdivision of this problem but of great importance, is the interpretation, or translation, or explanation to the public in general, of the applied scientific appurtenances that have become so much taken for granted, without which life would be entirely changed. As more of science is applied and an increasing number of new contributions to public welfare make themselves evident, this problem will be more acute, so that today there is a very definite need for a raising of the intellectual level of the non-scientist, along lines of scientific achievement. An example of this may be had by observing a prospective automobile driver receiving instruction on how to shift gears. A knowledge of the function of the clutch, of speeds, and of gear positions give a very good background of the general mechanics of the system, without which, trouble may be encountered.

One of the stages in which this general scientific knowledge is given, is to the student or to those who have a desire for the satisfaction of a natural curiosity.

It is for these that the "Survey of Physical Science" will have its greatest appeal. Although presented in the form of a text, it is not difficult for the average reader to digest. Each chapter of the book is devoted to a topic and while the topics follow each other in logical order, many are complete in themselves so that they may be eliminated or covered alone. The sun, stars, planets, earth, winds and weather, heat as a form of energy, mechanics, electricity, chemistry, etc. are some. Each is described and discussed as they relate to the everyday life of the reader. The number of topics and the extent to which they are covered is of course limited. The last chapter of the book is on the future of science. Here in a very brief form is given a summary of a few of the most pressing problems which the scientist must face tomorrow.

The work is well planned and the method of interlinking historic data with the general subject matter is to be commended. It is profusely illustrated with diagrams and pictures, and contains a subject index. From it may be had a cultural knowledge that often should prove very useful in a practical way. Many students may find inspiration to proceed through the more technical aspects of science.

R. H. OPPERMANN.

SOILLESS GROWTH OF PLANTS, by Carleton Ellis and Miller W. Swaney. 155 pages, plates, illustrations, 15 × 24 cms. New York, Reinhold Publishing Corporation, 1938. Price $2.75.

Considerable space, in recent years, has been devoted by the press to the growing of plants of various kinds in water, or in a sand and stone soil. The interest created is apparent by the numbers of certain kinds of plants growing in glass or earthen containers in the household for decorative purposes. There is now a surge of popular interest on a much broader front in this art which promises to grow to great proportions.

Soilless Growth of Plants will undoubtedly add greatly to technical as well as popular interest and activity in this fascinating field. Carleton Ellis, the senior author needs no introduction to the chemical world in general. Dr. Swaney received his Doctor's degree in Chemistry in 1935 from Purdue University, an institution preeminent in agricultural and horticultural research. The collaboration of these two authorities in laboratory tests and investigations has resulted in this book. It is written in a language not too technical for the average reader to understand so that it should prove useful to those who desire to grow plants by the methods described.

In the first chapter there is discussed the essential mechanism of plant life and the factors vitally important to flourishing plants. The role of the soil is emphasized, how it efficiently furnishes water and how it gives up its chemical elements so that the plant may grow. From here instruction in growing in mineral aggregates is given. An experiment is described in which a plant was removed from soil and placed in sand, and it is shown how the necessary chemical elements were furnished from external sources. Sub-irrigation is the next step. This differs from the sand culture in that the grain size of the mineral aggregate is larger and a different method of feeding chemicals is used. Going still further, growing in water is then discussed which consists essentially of suspending the plant above a nutrient solution and allowing its roots to dip into this solution.

The principles so far covered are enlarged upon in the chapter on household plant culture which gives explicit directions.

The commercial aspects of the subject are gone into at some length. It is pointed out that there is a strong possibility that the time is not too distant when the man in the greenhouse will produce plants exclusively by nutrient solution methods. There are certain very definite advantages of this method. Among those cited are the elimination of countless soil diseases, drouth, and the operation in localities where soil is either absent or unfit.

The results achieved as described in this book are of such magnitude that attention is bound to be drawn both domestically and commercially. The presentation is authoritative, complete, and interesting to a large group of readers.

R. H. OPPERMANN.

DIFFUSION UND CHEMISCHE REAKTION IN FESTEN STOFFEN, von Dr. Wilhelm Jost. 231 pages, illustrations, tables, 15 × 23 cms. Dresden, Theodor Steinkopff, 1937. Price 20 R.M.

When a reaction takes place in a gas or in a stirred liquid, we can visualize the reacting components as being always in contact with each other. The reaction velocity will then depend upon the energy relations between the various reactants and products.

If however one or both of the reactants are a solid, these simple conditions no longer hold. The reaction velocity will then depend not only on the energy relations existing between the components but also on the rate with which the reactants and products are brought in contact with one another; that is, on the rate of diffusion.

Reactions in the solid phase are of the highest importance in industry—in the formation of alloys, tarnishing and corrosion of metals, absorption of gases by solids—to mention a few examples, and it is entirely because of the difficulty, both experimental and theoretical, that the study of reactions in the solid phase has been somewhat neglected.

In this volume, Dr. Jost has attempted to cover the field in a systematic and accurate manner. He has, in the opinion of the reviewer, succeeded in his aim. The book is surprising in its thoroughness and able handling of the problem. The first chapter is devoted to a discussion of the diffusion laws and the solution of the diffusion equations for special cases. The theory of "Fehlordnungserscheinungen," which we may translate as "phenomena arising from imperfections in the crystal lattice" is taken up in Chapter II. Chapter III considers the elementary processes which take place in reactions in solids. In Chapter IV, the "coating processes," such as corrosion and tarnishing, are studied. Chapter V covers the general question of reactions in the solid state and describes the methods of investigation used.

This book is the second volume in the series known as "Die Chemische Reaktion." The first volume is "Grundlagen der Photochemie." Further contributions in the same series will be: "Gasreaktionen," by Prof. Dr. H. J. Shumacher, "Kinetik der Phasenbildung und Kristallwachstum," by Prof. Dr. M. Volmer, and "Polymerisationsreaktionen," by Prof. Dr. H. Mark.

It is believed to be the only book in any language which covers the field of reactions in the solid phase, and would represent a valuable addition to any chemical library.

GEORGE S. GARDNER.

SPECTROSCOPY IN SCIENCE AND INDUSTRY. Proceedings of the Fifth Summer Conference on Spectroscopy and its Applications, held at the Massachusetts Institute of Technology, July 19–22, 1937. 134 pages, illustrations, tables, 19 × 25 cms. New York, John Wiley & Sons, Inc., 1938. Price $3.00.

The Massachusetts Institute of Technology has been having summer conferences on spectroscopy and its applications for some years. The subject is one which reaches into many fields including physics, chemistry, metallurgy, biology, medicine, etc., and consequently the popularity of the conferences grew rapidly with the result that attendance had to be limited in order to insure the desired informality of the meetings. The diversity of workers interested in the subject is of course large and the papers presented at the conference if viewed as a whole give some idea of the present status of the subject in many of its fields of application.

The present volume has some 134 pages between paper covers and contains twenty-nine papers in slightly abbreviated form which were presented at the 1937 conference. A total of thirty-six papers were presented but seven were not included because they dealt with theoretical spectroscopy and therefore did not contribute to the main purpose of the book. Because of their importance and diversity, there is reason to believe that the papers in this book have been published in technical publications of the fields concerned, but to have them all in one place as in this book is a time saver to anyone desiring the proceedings of the 1937 conference. It is to be regretted that space limitations have necessitated elimination of much discussion following each paper.

R. H. OPPERMANN.

ECLIPSES OF THE SUN AND MOON, by Sir Frank Dyson and R.v.d. R. Woolley. 150 pages, plates, illustrations, 16 × 24 cms. Oxford, Clarendon Press, 1937. Price $5.00.

The eclipses of the sun and moon aside from being phenomena of striking beauty, are important for three reasons—historical, astrophysical, and general physical research. The importance of these is already reflected to us in many practical ways and it is reasonable to assume that a more complete knowledge may produce even greater results.

The book at hand presents accurate descriptions of actual observations of eclipses and endeavors to make immediate deductions. After a general introduction the causes and prediction of eclipses are discussed, from which the reader is taken through eclipses in relation to the physical state of the sun from 1836 to 1889, eclipse expeditions, the spectrum, the chromosphere, and corona. Because of the broad scope of the subject, the treatment of many parts is brief, apparatus is not described in detail, and the discussion does not venture far into physical theory. Nevertheless, the reader is given a comprehensive survey of the subject and many of the gaps in our knowledge are pointed out. The book contains some very interesting photographic reproductions which strengthen the treatment considerably. It is one of the International Series of Monographs on Physics.

R. H. OPPERMANN.

ASTRONOMY, A TEXTBOOK FOR UNIVERSITY AND COLLEGE STUDENTS, by Robert H. Baker. Third Edition. 527 pages, illustrations, 15 × 24 cms. New York, D. Van Nostrand Company, Inc., 1938. Price $3.75.

This is the third edition of a text on a subject that has made much progress in recent years and one which holds increasing fascination and interest. The first edition appeared in 1930, the second in 1933. This serves to illustrate the rapidity of appearance of new data and new viewpoints. From the scientific side it is little short of amazing when a comparison is made with like periods in history, even in recent times. From the popular or layman's side it is apparent everywhere that fascination is taking hold. Planetaria have come into existence that are used for instructing the public in the wonders of the universe, as for instance, the Fels Planetarium at The Franklin Institute, the result of which cannot help but arouse curiosity to the extent of ultimately extending further the search into the unknown.

"Astronomy" is a text on the subject for introductory college courses. As such the prerequisites are little more than what the average intelligent man or woman possesses today. There are several features of the book that stand out but the most prominent one is that the author has taken advantage of the interest in the subject plus the introductory stage of the work and combined these with the art of presentation so that the result can hardly be called a text, as texts are usually referred to, but a work that should have appeal to a greater circle than to students of a prescribed and specified course. The book can be said to "read" in addition to explain and instruct. It accomplishes its intent of satisfying a desire.

The plan is one of logical sequence beginning with discussions on the aspects of the sky and proceeding through the motions of the earth, the solar system, planets, the sun, stars, stellar motions, the Galactic System, and the Exterior Systems. Star maps, and reproductions of recent photographs such as those of reflection nebulae at the McDonald Observatory supplement the discussion, adding greatly to the comprehensiveness of the work. The topics are so arranged and presented that one, only casually interested in astronomy, glancing through the book will find the answers to many questions which occur when observing the nightly heavens. There are lists of questions at the end of chapters which show practical everyday application of the subject matter covered. A name and subject index add greatly to its value as a reference work.

The book fits well into its niche as an introduction. It furnishes a groundwork for further scientific study and is complete in itself in so far as providing a satisfactory explanation of the known facts and pointing out much of the problematical and unknown, to the reader of average intelligence.

R. H. OPPERMANN.

RADIO, A STUDY OF FIRST PRINCIPLES, by Elmer E. Burns. Third Edition, 293 pages, plates, illustrations, 14 × 20 cms. New York, D. Van Nostrand Company, Inc., 1938. Price $2.00.

Not so many years ago when radio reception became a popular pastime, an accompanying hobby assumed great proportions—that of constructing receiving sets. This hobby satisfied many inborn human desires, chief among which was the creation of an apparatus that performed an almost unbelievable thing.

Thousands upon thousands of men and women sought to learn how to build sets and, what is more important, how they operated. In pursuit of this hobby the fundamental laws and theory of this application of electricity became widely known. Since then the progress of radio has been so rapid that many of those early hobbyists have dropped out and radio transmission and reception to them is now an accepted thing along with other useful scientific developments. But this is not the death knell of popular interest in the subject. A great industry now exists which is becoming greater in itself as well as branching into many diversified lines. Witness also the 50,000 licensed amateur radio fans in the U. S. as well as the young people in high schools and colleges whose curiosity about radio will be satisfied, and the older folks who still have either an active or smouldering interest. It is to these that a book of this kind should have appeal.

This book gives clearly and simply the fundamental principles of electricity as applied to radio. It is in its third edition and is written for use in courses of high school grade, evening classes, and home study. As such there is eliminated everything but elementary mathematics and the general form of presentation is easily readable. The layout is so arranged as to fit the situation of the average reader who is interested first of all in the construction of radio receiving sets. Consideration therefore is given to a description of simple receiving circuits including the crystal detector, the tube detector, and amplification. From this, after interest has been cemented, electric batteries, magnetic action of an electric current, and electric circuits and Ohm's Law are discussed. Next, the testing of tubes is explained so that the reader can construct his own testing circuits. Following this the theory of alternating currents is given which prepares for chapters on detectors and amplifiers, and a more thorough examination of radio circuits. The last chapters of the book cover photoelectric cells, first principles of television, and radio measurements.

Ordinarily this order of presentation, if viewed from the standpoint of the older and more formal text, would seem to be illogical. This feature of the book, however, actually works to advantage in that the more spectacular is first exposed in a manner to encourage curiosity, which the information following endeavors to satisfy. In this way impressions on theory are made more definite for later chapters as well. All explanations in the book are based on the electron theory and they are so made that fair conception of the theory is gained.

The book can be recommended to those desiring an elementary treatment, for study as well as review. R. H. OPPERMANN.

ELEMENTARY THERMODYNAMICS, by Virgil Moring Faires. 219 pages, illustrations, 15 × 23 cms. New York, The Macmillan Company, 1938. Price $2.60.

The August number of the JOURNAL OF THE FRANKLIN INSTITUTE contained a review of Applied Thermodynamics by the same author which was followed by a 137-page book of Problems on Applied Thermodynamics by Faires and Brewer. The book at hand is very much like the former and contains in its appendix problems taken from the latter. In the preface the author states, "This book proposes to present for short courses in thermodynamics textual material that is complete for the topics offered. It differs from a more complete text on the subject only in that it presents fewer topics for consideration, not in that it presents

shortened discussions. It was felt that completeness in treatment of topics should not be sacrificed in order to include a wide range of material that would be appropriate for a course designed to be full in scope." The coverage of topics in this book is very similar to its predecessor, quite practical in places where necessary to illustrate a point or principle, and of sufficient detail to give a sound foundation for further study. R. H. OPPERMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 626, The Transition Phase in the Take-Off of an Airplane, by J. W. Wetmore. 11 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1938. Price 10 cents.

An investigation was undertaken to determine the character and importance of the transition phase between the ground run and steady climb in the take-off of an airplane and the effects of various factors on this phase and on the air-borne part of the take-off as a whole. The information was obtained from a series of step-by-step integrations, which defined the motion of the airplane during the transition and which were based on data derived from actual take-off tests of a Verville AT airplane. Both normal and zoom take-offs under several loading and take-off speed conditions were considered. The effects of a moderate wind with a corresponding wind gradient and the effect of proximity of the ground were also investigated.

The results show that, for normal take-offs, the best transition was realized at the lowest possible take-off speed. Moreover, this speed gave the shortest over-all take-off distance for normal take-offs. Zoom take-offs required a shorter over-all take-off run than normal take-offs, particularly with a heavy loading, if the obstacle to be cleared was sufficiently high, e.g., greater than 50 feet; no advantage was indicated for the airplane with a light loading if the height to be cleared was less. The error that would result from the neglect of the transition in the calculation of the air-borne distance of take-off was found to vary from 4 per cent. with the heaviest loading considered to −4 per cent. with the lightest loading for normal take-offs over a 100-foot obstacle; the percentage error was twice as great for a 50-foot obstacle. For zoom take-offs the error attained much greater values. The average wind gradient corresponding to a 5-mile-per-hour surface wind reduced the air-borne distance required to clear a 50-foot obstacle by about 9 per cent. with the lightest loading and 16 per cent. with the heaviest loading; for a 100-foot obstacle, the reduction was about 10 per cent. in both cases. The over-all reduction due to this wind was approximately twice that resulting from the wind gradient alone. A simple expression for the reduction of observed take-off performance to no-wind conditions is presented. Ground effect is shown to reduce the air-borne distance to attain a height of 50 feet by 10 per cent. with the lightest loading and 16 per cent. with the heaviest loading; for a 100-foot obstacle, the percentage reduction was about one-half as great.

No. 627, The Experimental and Calculated Characteristics of 22 Tapered Wings, by Raymond F. Anderson. 23 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1938. Price 10 cents.

The experimental and calculated aerodynamic characteristics of 22 tapered wings are compared, using tests made in the variable-density wind tunnel. The

wings had aspect ratios from 6 to 12 and taper ratios from 1.6 : 1 to 5 : 1. The compared characteristics are the pitching moment, the aerodynamic-center position, the lift-curve slope, the maximum lift coefficient, and the curves of drag. The method of obtaining the calculated values is based on the use of wing theory and experimentally determined airfoil section data. In general, the experimental and calculated characteristics are in sufficiently good agreement that the method may be applied to many problems of airplane design.

No. 629, On Some Reciprocal Relations in the Theory of Nonstationary Flows, by I. E. Garrick. 4 pages, illustrations, 23 × 29 cms. Washington, Government Printing Office, 1938. Price 10 cents.

In the theory of nonstationary flows about airfoils, the "indicial lift" function $k_1(s)$ of Wagner and the "alternating lift" function $C(k)$ of Theodorsen have fundamental significance. This paper reports on some interesting relations of the nature of Fourier transforms that exist between these functions. General problems in transient flows about airfoils may be given a unified broad treatment when these functions are employed. Certain approximate results also are reported which are of notable simplicity, and an analogy with transient electrical flows is drawn.

KONTINUIERLICHE SPEKTREN, von Dr. Wolfgang Finkelnburg. 369 pages, illustrations, 16 × 24 cms. Berlin, Julius Springer, 1938. Price 33 R.M.

This book contains the present knowledge of the continuous optical vision based on the situation of electronic-atomic and molecular physics. The divisions of the spectrum when ordinarily viewed are not sharply defined and knowledge of line and band spectroscopic phenomena is certainly now and will become a very practical necessity in many specialized fields of physics, chemistry and astronomy.

The book is complete in itself. It begins with an introduction of the nature of a survey giving the conception of the continuous spectrum and upon which it is at present based, the part that it plays in the various fields of scientific endeavors and some theoretical fundamentals. Then the general theory with respect to the electron spectrum is discussed followed by chapters on photoionization, emission, continuous wave absorption of free electrons, and disturbances of electron continuity. The molecular side of the subject is treated in quite some detail from all important viewpoints including the two-atom and many-atom molecule. The preparation of lines, and temperature and black radiation are thoroughly examined. The nature of the treatment is such that equal stress is laid on theoretical principles as on the experimental. Occasionally there appears an introductory portion to a topic minus the extensive supplemental mathematical explanation which may be taken as outside of the field of the book. Always, however, value is laid upon observed results. The subject matter is illustrated in the way of curves, tables, and drawings. There is a list of references, name and subject index, in the back of the book.

The presentation does well in accomplishing two purposes. First, it covers systematically and in detail the subject of continuous spectroscopy. Second, it accounts for the present position of the many branches of investigation as assist-

ance to those in different fields of work in the subject. It should be of interest to students and workers who read the German language.

R. H. OPPERMANN.

DER SMEKAL-RAMAN-EFFEKT, erganzungsband 1931–1937, von Dr. K. W. F. Kohlrausch. 288 pages, illustrations, 14 × 22 cms. Berlin, Julius Springer, 1938. Price 24 R.M.

More than six years have elapsed since the original book, "Der Smekal-Raman-Effekt," of this series was published. Since then considerable data have appeared which have been quite voluminous and have covered quite a large field. The present book is offered as a supplement to the former in that it brings the subject matter up-to-date by clarifying and assisting in the way of reference so that definite conclusions can be drawn. It begins with an introduction to the classical theory of light scattering from vibrating molecules and then gives attention to experimental technique. This is followed by a brief treatment on the frequency of rotation in the Raman spectrum and the spectrum of vibrating molecules. Molecular construction with relation to spectroscopic phenomena is given considerable discussion. There is the result of much labor in the reference lists including an alphabetical substance index, conveniently arranged for ready use, and a bibliography of literature substantiating results, arranged by years from 1931 to 1937 inclusive.

R. H. OPPERMANN.

PROBLEME DER TECHNISCHEN MAGNETISIERUNGSKURVE, VORTRAGE GEHALTEN IN GÖTTINGEN IM OKTOBER 1937, von R. Becker and others. 172 pages, illustrations, 16 × 24 cms. Berlin, Julius Springer, 1938. Price 16.50 R.M.

The progression of scientific knowledge is ever in the direction of the search for unknown properties and reasons for certain phenomena. Closely following this is the conversion of this knowledge into practical use. It has not been long ago that the various reasons for magnetic phenomena were little known but, as painstaking investigation continues, more light is thrown on this, which was, a quite narrow field. It has now become a highly specialized subject. In October 1937 a meeting was held in Göttingen for the purpose of discussing and revealing new knowledge on it. This book contains some ten papers presented there.

After an introduction by Professor Dr. R. Becker the following are presented: Versuche über grosse Barkhausen-Sprünge, Dr. K. J. Sixtus; Das Anwachsen der Ummagnetisierungskeime bei grossen Barkhausen-Sprüngen, Dr. W. Doring; Zur Deutung der Koerzitivkraft, Martin Kersten; Mechanismus der Koerzitivkrafterhöhung bei zwei verschiedenen tenären Legierungen, Dr. J. L. Snoek-Eindhoeven; Über magnetische und mechanische Nachwirkung, Dr. G. Richter; Versuche zur magnetischen Nachwirkung bei Wechselstrom, Dr. Herbert Schulze; Der Zerfall der Mischkristalle in den Co-Ni-Cu-Legierungen im festen Zustand, Dr. G. Masing; Die Analyse der Ausschiedungshärtung mit ferromagnetischen Messungen, Dr. Walther Gerlach; Über den Aufbau und die Anwendung einiger magnetischer Messverfahren für metallkundliche Untersuchungen, Dr. Heinrich Lange.

The papers are given in full together with curves and illustrations. At the end of the book there is a name and subject index.

R. H. OPPERMANN.

AN ENGINEER'S MISCELLANY, by Greville Bathe. 136 pages, plates, illustrations, 13 × 29 cms. Philadelphia, Patterson & White Company, 1938. Price $4.50.

The title of this book is perhaps the best that could be chosen for it. It is exactly an engineer's miscellany. It consists of ten brief but concise sketches of the nature of the historical from, and of interest to, an engineering point of view. Being a miscellany, there is no relation, one to the other, of the sketches. The first of these dwells on the early artisan as depicted in art. Here the art of engraving is taken as the starting point for recording how early engineering problems were tackled. The history and development of tools in this section make very interesting reading.

It will be recalled that model engineering is of comparatively recent origin. In fact it has not as yet come into full stride. The author first became interested in models as a boy, fifty years ago, and he entitles the second of his collection in this book, "The Commercial Toy Steam Engine of Fifty Years Ago." Passing from this description to the next sketch, there is a treatment of a somewhat forgotten era designated as the decorative era in machine design. The peak of this was from 1840 to 1860. The examples shown bring to mind that the idea of dressing up the modern steam locomotive is not altogether new. Then there is a digest of Fitch's steamboats followed by an article on the first high pressure steam engine in America, of Oliver Evans. Both of these subjects receive a noteworthy treatment, historically and technically.

The story of the Old Cornwall iron mine should interest every engineer and should provide double the appreciation to those who may visit that part of Pennsylvania. An introspection on the antiquity of the inclined plane on canals is considered, with the old Morris Canal as a representative example of this principle. Following this the topics bear on the Cornish engineering talent and its contribution to engineering history, the lift wheel pumping plant of the Chesapeake and Delaware Canal, and Christopher Colles and the Steam Engine.

The book offers well written stories of these ten topics that interested the author over a period of years to the extent of initiating considerable historical research. His correlation of data, biographical and mechanical, by way of illustrations and writing should become increasingly valuable as time goes on.

R. H. OPPERMANN.

SPRINKLE'S CONVERSION FORMULAS, by Leland W. Sprinkle. 122 pages, 10 × 16 cms. Philadelphia, P. Blakiston's Son & Co., Inc., 1938. Price $1.25.

This little volume (pocket size) contains data so conveniently arranged for ready use that it should be a handy tool to a great variety of workers. It is actually a list of conversion formulas in alphabetical order by name according to the unit of measurement, and what is more, the formula is already calculated so that in its use only one process, that of multiplication, is necessary. The list begins with "Acres" which is followed by "Amperes" on through the alphabet. Below the initial word, the multiplier is given that is necessary to use to arrive at the converted unit. Thus, under "Acres" is given the number by which "Acres" should be multiplied to equal "Square Chains," "Square Feet," "Square Hectometers," etc. Because of the alphabetical arrangement, no index to the book

is necessary. It is its own index. In order to make it still more useful it is cross referenced, i.e., both the original and converted units are listed in their proper alphabetical place so that for instance the user can convert Angstroms to Centimeters by looking under Angstroms, and Centimeters to Angstroms by looking under Centimeters, both objectives being accomplished by multiplication. In the back of the book is a table giving the relations applicable to the conversion formulas. This is also arranged alphabetically.

To appreciate how handy a tool this little book really is, one must see it, and give it a few trials. It covers units of weight and measure commonly used in many diverse fields of endeavor.

R. H. OPPERMANN.

EXPERIMENTAL PHYSICS, by Samuel Robinson Williams. 158 pages, illustrations, tables, 20 × 28 cms. Boston, Ginn and Company, 1937. Price $1.00.

The author states in the Preface of this book that it is meant to be a quite flexible laboratory manual for the student beginning his study of the subject, i.e., it conforms with the ideas of those who insist that laboratory experiments must be preceded by classroom instruction on the general subject matter, and those others who contend that, if the student has had an experimental approach to the subject, the discussions in the classroom will be more vital.

In preparation of the work proper there are, first, three experiments. These deal with the composition and resolution of vectors, moments of forces—torques, and the motion of a body falling through space under the force of gravity. The author states that these experiments are the "terrorizing" ones for the student beginner, and he has accordingly treated and arranged them with special care in an effort to create an underlying interest in the subject.

Following these there are thirty-nine experiments. Each has an introduction, explanation of theory, and procedure directions. All are well illustrated. An appendix contains brief reference to the trigonometric functions, units of measurement, etc. The book should be of interest to teachers of elementary physics, students, and those who aspire to know something of the fundamentals of physics.

R. H. OPPERMANN.

PUBLICATIONS RECEIVED.

Submarine, The Autobiography of Simon Lake, as told to Herbert Corey. 303 pages, plates, 13 × 20 cms. New York, D. Appleton-Century Company, Inc., 1938. Price $3.00.

Edison's Open Door, by Alfred O. Tate. 320 pages, plates, 14 × 22 cms. New York, E. P. Dutton & Co., Inc., 1938. Price $3.00.

Théorie Nouvelle de la Mécanique Statistique, par Th. De Donder. 83 pages, illustrations, 16 × 24 cms. Paris, Gauthier-Villars & Cie, 1938. Price 40 francs.

Fundamentals of Electricity and Magnetism, by Leonard B. Loeb. Second Edition, 554 pages, illustrations, 15 × 23 cms. New York, John Wiley & Sons, Inc., 1938. Price $4.00.

An Engineer's Miscellany, by Greville Bathe. 136 pages, plates, illustrations, 13 × 29 cms. Philadelphia, Patterson & White Company, 1938. Price $4.50.

Elementary Survey of Physics, by Arthur E. Haas with the collaboration of Ira M. Freeman. 203 pages, illustrations, 13 × 20 cms. New York, E. P. Dutton & Co., Inc., 1938. Price $1.90.

Grimsehls Lehrbuch der Physik, Professor Dr. R. Tomaschek. Zweiter Band, Erster Teil, 866 pages, plates, illustrations, 15 × 23 cms. Leipzig, B. G. Teubner, 1938. Price 26 R.M.

Tables of Functions with Formulae and Curves, by Dr. Eugen Jahnke and Fritz Emde. Third Edition, 303 pages, illustrations, 16 × 24 cms. Leipzig, B. G. Teubner, 1938. Price 15 R.M.

Quelques Techniques Actuelles en Physique Nucléaire, par Jean Thibaud, Louis Cartan et Paul Comparat. 276 pages, plates, illustrations, 16 × 25 cms. Paris, Gauthier-Villars, 1938. Price 100 francs.

Der Indikator, von Prof. K. J. deJuhasz und Dr.-Ing. J. Geiger. 293 pages, illustrations, 16 × 24 cms. Berlin, Julius Springer, 1938. Price 28.80 R.M.

The Silver Magnet, Fifty Years in a Mexican Silver Mine, by Grant Shepherd. 302 pages, plates, 14 × 21 cms. New York, E. P. Dutton & Co., Inc., 1938. Price $3.00.

A Preface to Mathematics, by C. E. Van Horn. 124 pages, illustrations, 13 × 20 cms. Boston, Chapman and Grimes, Inc., 1938.

The Magic Wand of Science, by Eugene W. Nelson. 213 pages, plates, illustrations, 13 × 19 cms. New York, E. P. Dutton & Company, Inc., 1938. Price $2.00.

Chemistry of the Proteins, by Dorothy Jordan Lloyd and Agnes Shore. Second Edition, 532 pages, illustrations, 13 × 20 cms. Philadelphia, P. Blakiston's Son & Co., Inc., 1938. Price $5.50.

Route Surveys, A Pocket Book for the Survey, Design, and Construction of Railways, Highways, Canals, Flumes, Levees, Pipe Lines, Transmission Lines, and other Route Constructions, by Harry Rubey. 261 pages, illustrations, 11 × 17 cms. New York, The Macmillan Company, 1938. Price $3.75.

Manuel du Savonnier, par A. Matagrin. 268 pages, illustrations, 14 × 18 cms. Paris, Gauthier-Villars, 1938.

Structural Design, by Carlton Thomas Bishop. 254 pages, illustrations, 15 × 23 cms. New York, John Wiley & Sons, Inc., 1938. Price $3.50.

The Elements of Ferrous Metallurgy, by Joseph L. Rosenholtz and Joseph F. Oesterle. Second Edition, 258 pages, plates, illustrations, 15 × 23 cms. New York, John Wiley & Sons, Inc., 1938. Price $3.00.

Starcraft, by William H. Barton, Jr., and Joseph Maron Joseph. 228 pages, illustrations, 15 × 23 cms. New York, McGraw-Hill Book Company, Inc., 1938. Price $2.50.

Alternating Current Circuits, by Russell M. Kerchner and George F. Corcoran. 510 pages, illustrations, 15 × 23 cms. New York, John Wiley & Sons, Inc., 1938. Price $4.75.

Electric Power Circuits, Theory and Applications, by O. G. C. Dahl. Volume II, Power System Stability. 698 pages, illustrations, 15 × 23 cms. New York, McGraw-Hill Book Company, Inc., 1938. Price $7.00.

Electromagnetics, A Discussion of Fundamentals, by Alfred O'Rahilly. 884 pages, illustrations, 14 × 22 cms. New York, Longmans, Green and Co., 1938. Price $12.50.

The Sun, Its Phenomena and Physical Features, by Giorgio Abetti. 350 pages, illustrations, 14 × 23 cms. New York, D. Van Nostrand Company, Inc., 1938. Price $5.00.

Année Polaire Internationale 1932–1933. Participation Francaise. Tome II. 259 pages, illustrations, 25 × 33 cms. Paris, Gauthier-Villars, 1938.

National Advisory Committee for Aeronautics, Twenty-Third Annual Report, 1937. Including Technical Reports Nos. 577 to 611. 741 pages, illustrations, 22 × 29 cms. Washington, Superintendent of Documents, 1938. Price $2.50. Technical Notes: No. 656, Hydrodynamic and Aerodynamic Tests of Models of Floats for Single-Float Seaplanes, N.A.C.A. Models 41-D, 41-E, 61-A, 73, and 73-A, by J. B. Parkinson and R. O. House. 60 pages, illustrations. No. 657, Tank Tests to Show the Effect of Rivet Heads on the Water Performance of a Seaplane Float, by J. B. Parkinson. 21 pages, illustrations. No. 658, Generalized Analysis of Experimental Observations in Problems of Elastic Stability, by Eugene E. Lundquist. 17 pages, illustrations. No. 659, Wind-Tunnel Tests of Three Lateral Control Devices in Combination with a Full-Span Slotted Flap on an N.A.C.A. 23012 Airfoil, by Carl J. Wenzinger and Millard J. Bamber. 17 pages, illustrations. No. 660, Fatigue Testing of Wing Beams by the Resonance Method, by William M. Bleakney. 45 pages, illustrations. No. 661, Wind-Tunnel Investigation of Rectangular and Tapered N.A.C.A. 23012 Wings with Plain Ailerons and Full-Span Split Flaps. 33 pages, illustrations. 6 pamphlets, 20 × 26 cms. Washington, Committee, 1938.

U. S. Department of Commerce. Building Materials and Structures Report BMSl. Research on Building Materials and Structures for Use in Low-Cost Housing, by Hugh L. Dryden. 5 pages, 20 × 27 cms. Washington, Superintendent of Documents, 1938. Price 10 cents.

Bell Telephone System, Monographs: B-1075, Thyratrons for Grid-Controlled Rectifier Service, by G. H. Rockwood. 11 pages, illustrations. B-1074, Characteristic Time Intervals in Telephonic Conversation, by A. C. Norwine and O. J. Murphy. 11 pages, illustrations. B-1073, The Occurrence and Effect of Lockout Occasioned by Two Echo Suppressors, by Arthur W. Horton, Jr. 23 pages, illustrations. B-1072, The Common Battery Anti-Sidetone Subscriber Set, by C. O. Gibbon. 13 pages, illustrations. B-1065, Focussing an X-Ray Beam by a Rocksalt Crystal, by R. M. Bozorth and F. E. Haworth. 18 pages, illustrations. B-1076, Arrangement of Molecules in a Single Layer and in Multiple Layers, by L. H. Germer and K. H. Storks. 25 pages, illustrations. 6 pamphlets, 15 × 23 cms. New York, Bell Laboratories, 1938.

Canada, Department of Mines and Resources. Investigations in Ore Dressing and Metallurgy (Testing and Research Laboratories) January to June, 1937. 158 pages, 16 × 25 cms. Ottawa, Bureau of Mines, 1938.

Automobile Facts and Figures. 1938 Edition. 96 pages, illustrations, 15 × 22 cms. New York, Automobile Manufacturers Association, Inc.

Carte gëologique du massif du Mont-Blanc (Partie Francaise) á L'échelle du 1 : 20,000, par M. M. Paul Courbin et Nicolaus Oulianoff. Le Tacul-Col du Geant, avec notice explicative. Map 48 × 66 cms., descriptive pamphlet 13.5 × 21.5 cms. Paris, G. Jacquart, 1938. Price 20 francs.

CURRENT TOPICS.

World's Deepest Oil Well a Test of Equipment and Drilling Methods.—A. H. BELL. (*Mining and Metallurgy*, Vol. 19, No. 379.) The deepest hole in the earth, and the deepest producing oil well is that of the Continental Oil Co., completed recently in the San Joaquin valley about four miles west of Wasco, California. It penetrated the earth's crust to a depth of 15,004 ft.—almost three miles—a depth that exceeds by over 2200 ft. that of the previous record holder in western Texas. The new well was bottomed in what is possibly Domengine-Avenal Eocene sand, and is producing oil at from 13,092 to 13,175 ft. from the Middle Miocene equivalent to the Rio Bravo sand. It was drilled in 284 days and completed on production in 296 days. The hole was surveyed at 11,570 feet, at which point it was found to be only 21 ft. from its vertical projection, and the maximum deviation was at that depth. This unusually straight and vertical course of the hole together with frequent setting of casing to eliminate extreme lengths of open hole undoubtedly contributed materially to the success of the project. Temperature readings, taken under difficult conditions, indicated a temperature gradient ranging from 196 deg. F. at 6000 ft. to 268 deg. at 15,000 ft. or 1 deg. increase for every 125 ft. The similarity of temperatures in the lower horizons to correlative horizons in other wells at shallower depths, suggests the possibility that the distance of a given subsurface point above basement rocks has more bearing on its temperature than its distance below the surface of the earth. A preliminary subsurface pressure transverse run after production had been stopped for 24 hours indicated a range from 2950 lb. per sq. in. at 5000 ft. to 5650 lb. at 13,175 ft. In drilling a well of this kind very careful attention must be given to safety factors in the design and rating of equipment.

R. H. O.

Gas Immersion Steam Boiler.—J. B. NEALEY. (*American Gas Journal*, Vol. 149, No. 1.) A new type of gas boiler designed to eliminate the old trouble of tube failure due to corrosion has recently been installed in the plant of the Moon Manufacturing Co., Chicago, makers of steam turbine electric generators The boiler is used for block testing and running these turbo-generator sets. Due to the fact that it lies in a horizontal position the tubes are under water for their entire length. This particular boiler is a 20 horsepower

unit and the steam is used at 100 to 125 lbs. pressure. It is 30 in. in diameter and 8 ft. long and is said to raise 100 lbs. of steam pressure from cold in 12 to 15 minutes. Heat is supplied through the series of tubes making two complete passes each and giving a total of 14 ft. of flue gas travel each. Sediment is collected in an 8 in. space below the lowest tubes in the bottom of the boiler. As it is never heated directly it does not form the usual scale and cake and is easily removed by blow-down methods Firing is accomplished by a battery of specially constructed immersion gas burners, each of which fires into the end of one tube. A long needle shape flame reaches back into the tubes. A blower supplies air for combustion. The first pass of tubes is in the upper portion of the boiler and the return in the lower. As the hottest portion of these tubes is just below the water level, steam is generated very quickly while the water in the bottom is receiving a quick preheat from the waste products of combustion going through the second pass of the tubes. This boiler is automatic in all details and needs no attention whatever. An automatic steam pressure control, low water fuel cut off and safety pilot are part of the equipment. With this setup steam is said to leave the heater at 338 deg. F. while the flue gases in the stack are only 350 deg. A combustion efficiency of 80 per cent. at 100 lbs. steam pressure is guaranteed.

R. H. O.

Air-Conditioning for Precise Cotton Classing and Research.—Cotton classing and fiber research by the U. S. Department of Agriculture at Washington soon will be conducted under conditions of humidity, temperature, and air currents far more accurately controlled than heretofore, the Bureau of Agricultural Economics has announced. It is believed that the Bureau's cotton classing room and laboratories, now being air-conditioned, will be the first to be equipped with a combination of several new engineering features. Special control instruments make this air-conditioned, cotton "work shop" a precision installation. The controls in certain of the laboratories permit any variation of temperature from 32 degrees Fahrenheit to 100 degrees. They allow any relative humidity within a range from 10 per cent. up to 97 per cent.—practically to the point of saturation. Any temperature that it is desired to maintain will not vary more than one degree up or down. For the cotton classing room a 70 degree temperature and a humidity of 65 per cent. will be maintained. These are standard conditions for classing under the Cotton Standards Act. In the air-conditioned laboratories will be made studies of water absorption and general behavior of cotton fiber under a wide range of temperature condi-

tions and relative humidity. Relative humidity is to be measured, recorded and controlled directly and independently of temperature control, and is perhaps the first textile installation so regulated. The adding to or taking out of water vapor from the air to maintain a desired humidity is done with chemicals that have special affinity for water. Perhaps the most novel of the engineering detail is the reliance upon radiation of heat to and from coils placed in the rooms themselves. For example, chilled water in summer is passed through the radiators that are used for winter heating. In one particular laboratory room such radiator coils are on walls and ceiling and even embedded in the floor. This system will minimize air currents by excluding direct wind velocities created by some types of air-conditioning systems.

R. H. O.

Chemical Dehumidification of Air.—H. J. KAUFMAN. (*Heating, Piping and Air Conditioning*, Vol. 10, No 7.) Automatically controlled electrical substations with outside transformers and little or no heat producing equipment within the buildings are subject to condensation of moisture on the floors, walls, ceilings, and equipment when the temperature of the exposed surfaces is lower than the dewpoint temperature of the air in contact therewith. The Consumers Power Co. of Michigan has many isolated and unattended substations where this condensation was a problem. Recently a chemical dehumidifying cabinet with automatic relative humidity control was installed for test purposes in Custer substation near Battle Creek. This substation is approximately 18 ft. by 52 ft. in size with a volume of 10,500 cu. ft. and was the worst from the standpoint of condensation. The temperature, relative humidity, and cabinet operation were automatically recorded for a period of 56 days. During this test period 180 lb. of water were removed from the air at a cost of $2.25 for chemical. The power cost was that of operating a ¼ hp. motor at 50 per cent. load for a portion of the time at substation rates. The dehydrating cabinet has a storage space which is periodically filled with chemical and which has capacity for absorbing large quantities of water at intermittent periods. The chemical is wasted after absorbing the maximum amount of water from the air. These cabinets are equally satisfactory in small and large substations.

R. H. O.

Beamascope—New Radio Development.—(*General Electric Review*, Vol. 41, No. 7.) That outdoor antenna, universal but troublesome symbol of radio reception since the beginning of broadcasting,

is about to vanish from the scene, has been indicated by commercial engineers of General Electric in demonstrating its successor—a new device that has been christened the Beamascope. It consists of a self-contained acceptor circuit completely enclosed by a rejector winding, or shield. The winding form is made of a special type of wood, thoroughly impregnated to prevent warping and a loosening of the acceptor winding. The shield or rejector winding consists of many fine wires surrounding the acceptor circuit and connected to the receiver chasis. Termed the rejector circuit, the shield is of the Faraday type, shielding the coil electrostatically but not electromagnetically. When a receiver is first installed in a home the Beamascope is rotated and left in position of minimum noise pick-up. The adjustment is made preferably with the antenna tuned to a weak signal. The device necessitates no change in the appearance of the cabinet. There are three definite advantages. It is first of all a better antenna because it has been correlated with the design of the receiver in which it is installed. Second, the elimination of antenna and ground leads. Finally it discriminates against undesirable noise interference, ordinarily carried to a receiver by the electrostatic portion of the radio signal.

R. H. O.

New " Weather " Tunnel and Test Tracks.—The News Edition of *Industrial and Engineering Chemistry*, Vol. 16, No. 13, states that a huge new "weather" tunnel, the first of its kind ever built solely for scientific research in motor car design, has been put in operation at the Ford Motor Co. Engineering Laboratory in Dearborn, Mich. A 500 ton refrigerating system powerful enough to maintain a temperature of −20 deg. F. in the tunnel, and other devices including a rain machine and a sand and dust blower, enable the engineers to duplicate a wide variety of extreme conditions under which motor cars are forced to operate in actual use. A "cold" chamber has been installed, in which temperatures as low as −40 deg. F. can be maintained. The room will be used for cold weather tests of engine, oil, battery, and starter. The tunnel itself is a rectangular structure, 124 feet long, 35 feet wide, and 14 feet high enclosing an elliptical chamber 10 feet in diameter. In this chamber air can be circulated at velocities as high as 85 miles an hour. The air is driven by a 400 horsepower electric motor turning a 10 foot 3 blade propeller. The course of the air stream around the turns in the tunnel chamber is directed by air-foil steel vanes. A control station is located outside the tunnel. The tunnel walls at the station are formed of multiple layers of heavy glass framed in steel, enabling engineers to watch the cars under test. Instruments register the

speed, temperature, barometric pressure, and humidity of the air inside the tunnel; the engine speed, fuel consumption, air-fuel ratio of the carburetor mixture, and the efficiency of the fuel combustion; as well as the temperatures of the engine compartment and of the intake and outlet cooling water, the intake vacuum, the exhaust temperature and pressure, the engine oil pressure and temperature, and scores of other readings.

R. H. O.

New Mechanical Weather Observer Replaces Airplanes at 6 Stations.—A combined weather observatory and radio broadcasting station weighing less than two pounds—the "radiometeorograph"—will replace the airplane in making upper-air soundings at six Weather Bureau stations soon according to Dr. W. R. Gregg, Chief of the Weather Bureau. At these stations this newest aid to forecasters will be carried aloft each morning by a small balloon inflated with helium. The response of weather-sensitive elements in the observatory end of the instrument to changes in the surrounding atmosphere causes a miniature wireless station to send out sound signals. From their audio frequency, these signals, received at a ground station, can be translated into terms of temperature, pressure, and humidity of the air at all heights reached by the robot weather observer. "Regular use of the radiometeorograph," Doctor Gregg says, "marks the beginning of a new epoch in meteorological service." Until upper air data became available, forecasts depended mainly on ground observations of the distribution and movement of air masses. This system finally reached its limit in accuracy. With more upper-air data, obtained by self-recording instruments borne by balloons and airplanes, greater accuracy in forecasting now becomes possible. Modern exploration of the upper air shows that weather is determined not by air masses as such, but by their interaction along the boundaries where they come together. Air masses from different regions—polar, equatorial, continental, and marine—tend to keep their individual identities in temperature, pressure, and movement over comparatively long periods. The weather-making process is most active at their surfaces of contact. Here are formed discontinuities in temperature, pressure, and movement—the so-called "fronts." The radiometeorograph spots these "fronts" for the forecaster. The radiometeorograph has several advantages over the airplane as a weather explorer. It can go higher, it can take off in bad weather, and it reports its findings instantly. The weather-sensitive elements of the new radiometerograph are several strands of human hair, which tighten or loosen as the air around them becomes drier

or more moist, and a small glass tube filled with sulphuric acid which responds to changes in temperature.

R. H. O.

Drum Construction is Improved.—(*Chemical and Metallurgical Engineering*, Vol. 45, No. 7.) The Steel Barrels and Drums Committee of the Manufacturing Chemists Association has been successful in obtaining approval of changes in the specifications for the 18 gage, 55 gallon and the 19 gage, 30 gallon steel drums which are widely used for transportation of non-dangerous liquids and other inflammable liquids flashing between 20° F. and 80° F. The change only applies to bung drums. Open head drums have not been changed. The new drum weighs 9½ lb. less than the present drum in the 55 gallon size. This change has been based on two basic facts which were proved by the Committee. In the first place the present drum is a satisfactory container as its transportation record is of the best. Secondly it was found that the drum was unbalanced in strength as the side walls are stronger than the heads. It was therefore logical to reduce the gage of the side walls to more nearly approximate the degree of resistance to abuse which is built into the heads. Twenty gage steel was found to be more flexible than 18 and this has resulted in a greater capacity of the drums to absorb shocks. The Committee conducted hydrostatic tests, drop tests, and impact tests to prove their contention.

R. H. O.

Making Gas Electrically.—Extracts from a paper by J. KEILLOR on developments of the gas industry in Canada, in the *Gas World*, Vol. CIX, No. 2815, contain mention of a Toronto experiment conducted by A. T. Stuart of the Hydro-electric Power Commission of Ontario which shows how complete gasification of coal or coke, etc., can be accomplished in a plant specially designed, using oxygen produced from water by electrolysis. For many years it has been realized that the solution of the problem of the economical and complete conversion of coal into gas will depend upon large supplies of cheap oxygen. Water contains both oxygen and hydrogen which can be separated in the highest purity, and, as it is used in the gas process in the form of steam, in a sense, gasworks are hydrogen factories. The Commission is perhaps the first to demonstrate on a commercial scale how complete gasification of solid fuel is accomplished electrically, producing gas of similar composition, heat value, and specific gravity to that now being distributed in city mains. The plant was constructed with the coöperation of an American firm. Some 2,000 cubic feet of oxygen and 4,000 cubic

feet of hydrogen are produced per hour. A standard type gas producer having stationary grates was installed for operation with oxygen and steam. Some fifteen tests were made extending over periods of 6 to 15 hours after operating conditions were established. Although it is a simple matter to carburet the gases produced to present standards, and although costs would still be less than with competitive methods, the lowest possible costs would be reached if gas of a calorific value of 333 B.T.U. could be sold on a therm basis. Lowest costs for materials per therm of gas would be reached if neither enrichment nor incorporation of electrolytic hydrogen were necessary.

R. H. O.

Guarding Against Storms.—The effect of weather is of very great importance in the maintenance and operation of electric public utility systems. A good picture of the vigilance which must be kept by operators is given in an article in *Around the System*, Vol. 3, No. 7, a publication for employees of the Consolidated Edison Co. of New York and affiliated companies. Sudden storms must be anticipated in order that turbines in generating plants be started and warmed up for the production of increased electric power demand. The time required is from one to two hours before they may be put on the line. The demand because of daytime darkening of the New York sky, some years ago, between 3:30 and 4:30 on a June afternoon, was increased to 65 per cent. above normal at that hour. In view of these conditions constant telephone communication over hundreds of miles in all directions must be maintained, as well as weather news by radio and the findings of the Weather Bureau. A new storm detector device is also used, developed by R. Lombard of the Consolidated Co. It is designed on radio principles, picking up electric charges by an antenna over the generating station. The current illuminates a neon tube, the light from which falls on a photo-electric cell. The amplified current from this cell activates a relay which rings a chime. So sensitive is the instrument that it operates on a very minute electric discharge, making it susceptible to small or distant storm disturbances. At the indicator panel the system operator not only watches the approach of a storm but estimates the rapidity with which it is traveling by the frequency of the chime.

R. H. O.

Fellowships.—In order to improve the quality of education and the practice of the arts and professions in the United States, to foster research, and to provide for the cause of better international

understanding, the John Simon Guggenheim Memorial Foundation, established by former United States Senator and Mrs. Simon Guggenheim as a memorial to a son who died April 26, 1922, offers a limited number of Fellowships tenable under the freest possible conditions, for research in any field of knowledge and for creative work in any of the fine arts, including music. In the main, the Fellowships have been granted only for work abroad; but for 1939–40, in exceptional cases, a limited number may be granted for work in the United States. The Fellowships will be awarded by the Trustees upon nominations made by a Committee of Selection.

R. H. O.

Water Levels and Artesian Pressure in the United States in 1937.—The rock formations of the earth are great natural underground reservoirs in which a part of the water derived from rain and snow is stored to supply the wells and springs and to maintain the flow of the streams during periods of fair weather. The water levels in wells register the stages of these natural reservoirs; they show to what extent the water supplies are depleted by drought or by heavy pumping for public waterworks, irrigation, or industrial uses and to what extent they are replenished in seasons of abundant rainfall or melting snow. The pressures recorded on flowing wells also indicate the extent of depletion or replenishment of the artesian reservoirs. The Geological Survey, of the United States Department of the Interior, has in preparation the third volume of an annual series on ground-water levels and artesian pressure, the first and second of which were published as Geological Survey Water-Supply Papers 777 and 817 respectively. This series of reports is in a sense an annual inventory of the water supplies of the parts of the country that it covers. The report in preparation gives records of water levels and artesian pressure in observation wells in 28 states and the territory of Hawaii that were obtained chiefly in 1937 by the Geological Survey and coöperating Federal, State, Territorial, county, and local agencies. It shows that in 1937 net rises of water level occurred in many observation wells unaffected by heavy withdrawals in the eastern and western parts of the United States, and net declines occurred generally in observation wells in the middle part. The annual changes in water level correspond rather closely to the departures from normal annual precipitation for these sections.

R. H. O.

Aerobiology Studies Pests That Come With the Wind.—A study of plant disease spores, pollen, and other microscopic objects carried

by air currents far above the earth is part of this year's research program of the U. S. Department of Agriculture. The National Research Council is coöperating as are other Government Departments, and educational institutions. The study will be directed by FRED C. MEIER, principal pathologist in the Department of Agriculture and chairman of the Committee of Aerobiology of the National Research Council. Mr. Meier will make airplane flights over the U. S. and adjacent waters this summer. Sampling the air up to high altitudes with a modified "sky hook"—the air sampling instrument used by Colonel Lindbergh, in coöperation with Mr. Meier in 1933—he will bring back living spores of fungi and bacteria for laboratory study. Spores collected on dirigible and airplane flights over the U. S. have given valuable information on the aerial movements of the spores of microörganisms that cause such plant diseases as black stem rust of grain, white pine blister rust, cedar rust of apples, and downy mildew of onions. Expansion of the new science of aerobiology, now possible with modern methods for exploring the upper air, will shed new light on the spread of microörganisms, viruses, pollen, and dusts, Mr. Meier says. Facts thus obtained would serve as a guide in devising improved methods for the control of certain fungus, bacterial, and virus diseases of plants. The expansion of aerobiology also will aid some other older sciences. For example, human pathology should profit by information providing another basis for developing more effective methods for dealing with hay fever and other allergic conditions and a better understanding of the possible spread of certain fungus, bacterial, and virus diseases of man.

R. H. O.

Refrigeration Used When Operating Distillate Well.—Quite often when drilling a well for oil, the forthcoming fluid, instead of oil, is a wet gas. The well is then known as a gas distillate well. MITCHELL TUCKER in the *Oil and Gas Journal*, Vol. 37, No. 11, describes a plant, the first of its kind, to comply with the growing conservation practice of pressure maintenance in oil or gas reservoirs. The removal of oil or gas from the ground naturally causes lowering of the pressure and finally depletion of the well. The Tide Water Associated Oil Co. and the Seaboard Oil Co. in East Texas have embarked on a program of high-pressure-refrigeration treatment of this wet gas. The process includes refrigeration from expansion of the gas and also employs the use of ammonia or other refrigerating mediums to aid in obtaining the definite temperatures so that the condensate can be extracted. This extraction of condensate is made under as high a pressure as possible for the reason that the resulting

dry gas is returned to the same earth formation from which it was taken and under high pressure there is a minimum horsepower required to do this. The return of the dry gas maintains the pressure of the surrounding territory. The condensate recovered is liquefiable hydrocarbons. The process is of special interest because until recently very little has been known about the behavior of complex mixtures at higher pressures, and until recently no method of calculation of the mechanics of condensation was considered available. The equipment throughout the plant is of most modern design and the plant is laid out and constructed in a manner to afford the greatest degree of efficiency, safety and flexibility for the addition of other units.

R. H. O.

Fluid Transmission—A Way to Eliminate Gear Shifting.—(*Transit Journal*, Vol. 82, No. 8.) Riders on buses in New York and Chicago will soon have an opportunity to observe the operation of a new type of hydraulic drive, which entirely eliminates the customary shifting of gears. This development climaxes five years of experimental work by General Motors Truck and Coach Co. and two years of operating tests. The new buses are to be 40 passenger capacity, powered with six cylinder, two cycle diesel engines. It has always been a problem of automotive design to convert the high speed and low torque rotation of the engine shaft to a slower rotation of the drive shaft with greater torque. Ordinarily, of course, the conversion is accomplished through a set of mechanical gears. When the hydraulic drive principle is applied, however, a centrifugal pump driven by the engine forces the fluid against the blades of a turbine, the shaft of which is connected to the wheels. Multiplication of torque in the ratio of 5 : 1 is possible when starting the vehicle. Then, as the vehicle gains speed the torque ratio is reduced. From the standpoint of the passenger the chief advantages are smooth acceleration and the absence of jerks, and the elimination of noise. From the standpoint of the operating company the outstanding advantages are fuel economy, lower maintenance costs, less driver fatigue, and fewer damage claims for falls caused by rough starts. The elimination of gear shift reduces vibration and prolongs the life of the vehicle. Acceleration is faster with hydraulic drive than with the conventional gear mechanism.

R. H. O.

Pickle-Liquor Plastic.—(*Business Week*, Aug. 20, 1938.) Very soon the Sharon Steel Corp. should finish equipping and begin

operating a new plant at Sharon, Pa., for converting waste "pickle liquor" into a versatile new material called Ferron. The company will operate as a first licensee under patents controlled by the Allied Development Corp. of Cleveland, and developed by H. S. COLTON. The waste "pickle liquor" is an aftermath of pickling steel in sulphuric and other acids to remove scale and oxides. Fresh acid can be added to the pickle bath as fast as it is consumed until a point is reached when the solution is so saturated with iron salts that it must be dumped into a handy stream. Though any free acid may be neutralized with lime before dumping, the ferrous sulphate in the liquor gradually hydrolizes in the stream, forming large volumes of weak sulphuric acid which attacks fish life and steel barges, piers, and boilers and condensers of factories located farther downstream. Ferron seems to be a promising solution to the problem. The process for making it is relatively simple and inexpensive and requires no great capital outlay for equipment. The resultant solid material is apparently a new composition of matter, being largely a co-precipitated iron hydroxide and calcium sulphate, tan in color. During manufacture, it goes through a state when it is plastic and may be molded into any desired form, which later sets into a hard mass by a combined process of drying and oxidation. Ferron resembles wood in that it may be sawed and nailed, but it is proof against fire, termites, and warping. It resembles plaster, but it withstands higher temperatures without losing its strength. It resembles fired clay and brick, but it weighs only one third as much. Its insulating value is high because it holds a high proportion of entrapped air. Silver kept in boxes made of Ferron will not tarnish.

R. H. O.